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JOURNAL OF PALEONTOLOGY

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VOLUME 31 MARCH, 1957 NUMBER 2

NORTHERN MIDCONTINENT MISSOURIAN FUSULINIDS

M. L. THOMPSON
University of Kansas, Lawrence

ABSTRACT—The fusulinid fauna of the Missourian Series of Kansas, Missouri, and Iowa is considered in this paper. The fauna includes one species each of *Millerella, Schubertella, Oketaella,* and *Fusulina,* six species of the new genus *Kansanella* which include one species of the new subgenus *Kansanella* (*Iowanella*) and five species of the new subgenus *Kansanella* (*Kansanella*), and nine species of the genus *Triticites.* One species of *Oketaella, O. inflata,* one species of the typical new subgenus *Kansanella* (*Kansanella*), *K.* (*K.*) *joensis,* and two species of the genus *Triticites, T. kawensis* and *T. iatensis,* are described as new. The stratigraphic distribution of the fusulinids throughout the series is discussed.

ROCKS of Missourian age are exposed over large areas of southwestern Iowa, northwestern Missouri, and eastern Kansas, and they are composed largely of highly fossiliferous marine limestones and shales alternating with non-marine sandstones and shales and some thin coal beds. They occur in sequences that are repeated a number of times from the base to the top of the series, generally with marine and non-marine beds alternating in regular sequences that are defined as cycles. The rocks of the marine phases of most Missourian cycles contain great numbers of fusulinid foraminifers, many of which are abundant throughout the region under consideration. Furthermore, Missourian marine rocks throughout most areas where known in America contain large faunas of fusulinids. Although small parts of the Missourian fusulinid fauna of the northern midcontinent region have been described on several occasions and by a number of workers, the entire fauna has not been brought together in a single treatment. It is the purpose of this paper to describe or illustrate all known Missourian fusulinids of the northern midcontinent region.

All Missourian fusulinids have been referred to the genus *Triticites* Girty, with the exception of the one species of *Wedekindellina* described by Newell & Keroher in 1937 from the Bethany Falls limestone and the single species of *Fusulina* described later from the same limestone by Thompson, Verville, & Lokke (1956). The present study indicates that many of the fusulinids formerly referred to *Triticites* are quite distinct from the type species of *Triticites, T. secalicus* (Say), and are being referred below to the new genus *Kansanella* and its two new subgenera *Kansanella* and *Iowanella.* This new genus belongs to the subfamily Schwagerininae, the same as *Triticites.*

Almost all of the fusulinids from the Desmoinesian Series belong to the fusulinid subfamily Fusulininae and include such common genera as *Fusulina, Wedekindellina,* and *Fusulinella.* The discovery in recent years of both *Fusulina* and *Wede-*

kindellina in basal Missourian rocks and shortly below Missourian rocks (Dennis limestone) with abundant faunas of *Triticites* encouraged Paul Lamerson to make a detailed field study of lower Missourian rocks of Iowa, Missouri, and eastern Kansas to determine if evidence could be found to indicate a stratigraphic break between the Bethany Falls limestone with *Fusulina* and *Wedekindellina* and the Winterset limestone above with the abundant faunas of *Triticites* and *Kansanella*. He studied in detail forty different exposures between Winterset, Iowa and Kansas City, Missouri and reached the following conclusions:

> There is no physical evidence to indicate a long break in sedimentation between the Bethany Falls limestone and the Winterset limestone. The Galesburg shale changes little in thickness and is lithologically uniform along the outcrop.

Lamerson studied all lithologic facies and made thin sections of most of the limestones. He obtained numerous sections of fusulinids from the Sniabar limestone member of Hertha limestone at Kansas City (M-40) and found abundant specimens of a new species of *Oketaella* described below as *O. inflata* Thompson & Lamerson, specimens of an undescribed species of *Schubertella*, and an undescribed species of *Millerella*. Although these fusulinids do not furnish precise stratigraphic information, they do represent the first fusulinids known from this part of the section.

The fauna from the Bethany Falls limestone seems more closely related to that from the Desmoinesian below, as recently discussed by Thompson, Verville, & Lokke (1956).

The next youngest Missourian fusulinids are in the Winterset limestone member of the Dennis limestone, and include the only known American species of the new subgenus *Iowanella* and *Triticites ohioensis*. This is the only known occurrence of *Iowanella* in America, except for the scarce specimens of the subgenotype in the Drum limestone shortly higher in the section. Typical species of the subgenus *Kansanella* are known first in the Dewey (Cement City) limestone member of the Drum limestone and are represented in practically every major marine unit throughout the remainder of the Missourian Series by the forms described below as *K.* (*K.*) *tenuis* from the Drum limestone, the Iola limestone, and the Wyandotte limestone, *K.* (*K.*) *neglecta* (Newell) from the Captain Creek limestone member of the Stanton limestone, *K.* (*K.*) *plicatula* (Merchant & Keroher) from the Plattsburg limestone and questionably from the Farley limestone member of the Wyandotte limestone; *K.* (*K.*) *osagensis* (Newell) from Missourian rocks of northern Oklahoma; and *K.* (*K.*) *joensis*, n.sp., from the Iatan limestone.

The subgenus *Kansanella* (*Kansanella*) is also represented by exceedingly abundant undescribed specimens in lower Virgilian rocks up to the Lecompton limestone. There does not seem to be any pronounced and distinct change within this genus across the Missourian and Virgilian boundary. About the only changes noted are a gradual increase in the weight of the axial fillings and some changes in shell shape.

The oldest *Triticites* in the Missourian of the northern midcontinent region is *T. ohioensis* Thompson so abundant in the Winterset limestone member of the Dennis limestone. Representatives of *Triticites* are less abundant throughout the remainder of the Missourian than are representatives of *Kansanella*, but *Triticites* does occur in all major limestone and marine shale units of the cycles from the Winterset to the top of the series and includes *T. nebraskensis* Thompson from the Cherryvale shale, *T. burgessae* Burma from the upper part of the Cherryvale, *T. pygmaeus* Dunbar & Condra from lower Missourian of Nebraska, *T. collus* Burma from the Drum limestone, *T. primarius* Merchant & Keroher from the Big Lake shale member of the Stanton limestone, *T. newelli* Burma from the South Bend limestone member of the Stanton limestone, *T. kawensis*, n.sp., from the Little Kaw limestone member of the Stanton limestone, and *T. iatensis*, n. sp., from the Iatan limestone.

Species of *Triticites* in upper Missourian rocks gradually attain thicker walls and relatively thicker and larger shells and resemble closely lower Virgilian species of the genus, such as *T. orizyformis* Newell from the Westphalia limestone of the Douglas group. The major change noted among

Triticites in going up in lower Virgilian rocks is a relative increase in wall thickness and a general increase in shell size. The most pronounced evolutionary changes which took place among the *Triticites* of the Virgilian Series is a gradual increase in the spirothecal thickness, gradual increase in the shell size, and a gradual increase in the size of the proloculus. The first distinctly inflated and short species of *Triticites* are found in the northern midcontinent region a short distance above the base of the Virgilian and in rocks near the age of the Oread limestone.

The stratigraphic distribution of the fusulinids described or discussed in this paper are illustrated on the accompanying stratigraphic diagrams of Missourian rocks of Kansas, Iowa, and Missouri (Text-fig. 1, 2).

Thanks are extended to the many organizations and individuals who have helped with this study. Special thanks are expressed to the Kansas Geological Survey and to the present and former graduate students Don Bebout, Dave Bostwick, Wm. King, Don Lokke, and Walter Moore. The Research Committee of the Graduate School of the University of Kansas furnished funds for production of part of the plates. All new material used in this study is in the author's collection.

COLLECTION LOCALITIES

Iowa

I-2. Bethany Falls limestone; 8 to 10 feet above the base of the limestone, in the roadcut of Highway 169, just west of the main quarry south of Winterset, west half sec. 6, T. 75 N., R. 27 W., Madison County.

I-6. Cherryvale shale; 4 feet from top of shale, on the east side of the road, about 3 miles southwest of the town of Winterset, NE¼, sec. 11, T. 75 N., R. 28 W., Madison County.

I-8. Dewey (Cement City) limestone; about 3 feet from top of limestone, same locality as *I-6.*

I-44. Winterset limestone; near the middle of the limestone, in the old quarry on south edge of Winterset, in the west half sec. 6, T. 75 N., R. 37 W., Madison County.

I-45. Dewey (Cement City) limestone; about 1.5 miles west and 1.3 miles south of Winterset on Iowa Highway 2. NW¼, sec. 10, T. 75 N., R. 38 W., Madison County.

I-47. Cherryvale shale; about 4 feet below top, same locality as *I-45.*

I-48. Bethany Falls limestone; same locality as *I-2.*

I-49. Cherryvale shale; near top, same locality as *I-6.*

I-50. Winterset limestone; upper fusulinid shale above *I-44*, same locality as *I-44.*

I-52. Cherryvale shale; about 9 feet below top, same locality as *I-45.*

I-53. Winterset limestone; about 4 feet below *I-44*, same locality as *I-44.*

I-54. Dewey (Cement City) limestone; about 3 feet below top, same locality as *I-45.*

I-59. Westerville limestone; on west side of the north-south road, SE¼, sec. 25, T. 69 N., R. 27 W., Decatur County.

I-60. Argentine limestone; 200 yards northeast of bridge over Middle River on Iowa Highway 2, west of Winterset.

Kansas

K-33. Bethany Falls limestone; Morris Quarry. ½ mile east of Morris.

K-179. Farley limestone; Cement Plant Quarry, Bonner Springs.

K-182. Iola limestone; on U.S. Highway 75, north of Louisburg, SW¼, sec. 8, T. 16 S., R. 25 E., Miami County.

K-191. Rock Lake shale; west sec. 31, T. 26 S., R. 15 E., Woodson County.

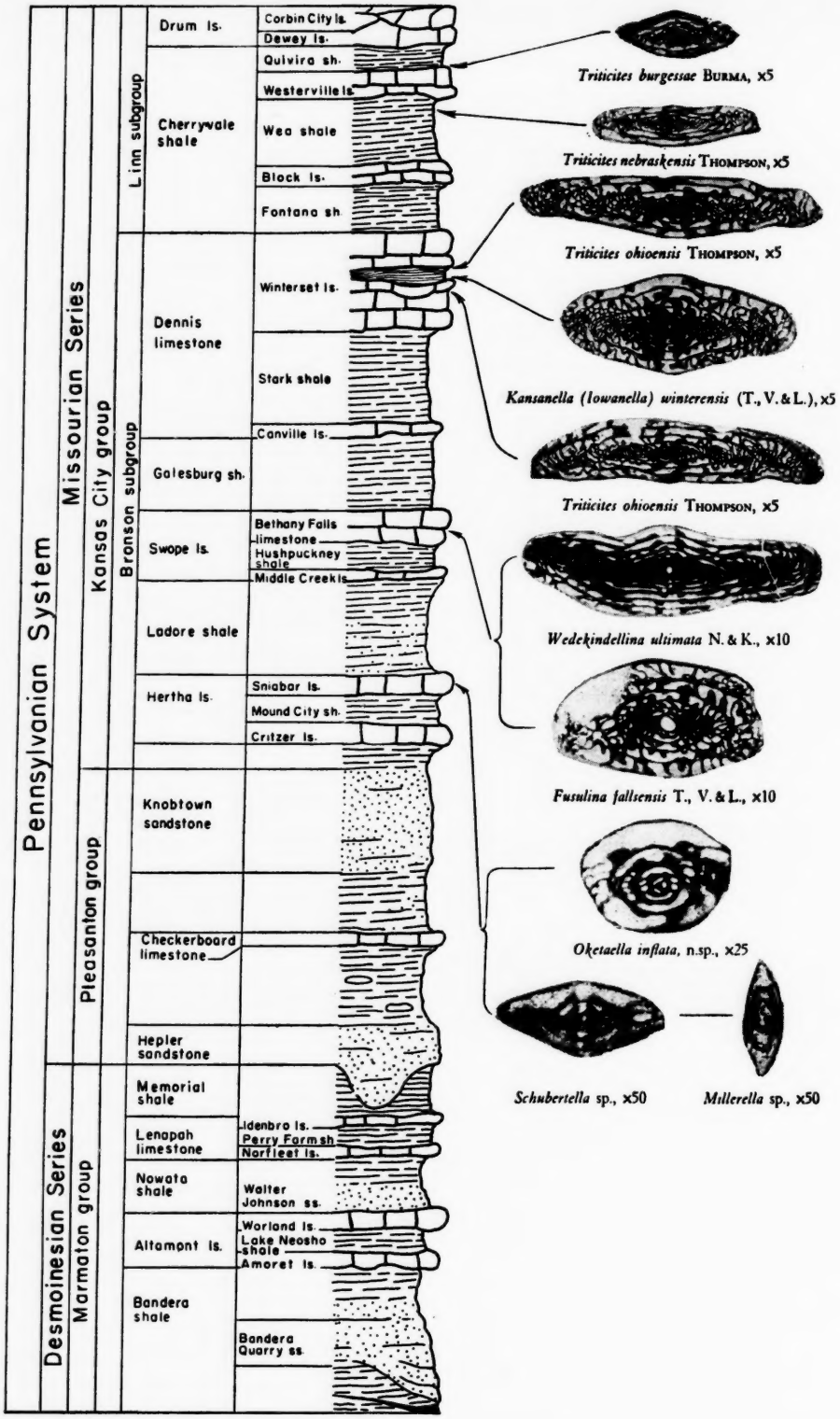
K-214. Captain Creek limestone; about 0.2 miles north of the old town of Pressonville, in old quarry just to east of the road, sec. 30, T. 16 S., R. 22 E., Miami County.

K-215. South Bend limestone?; in barnyard just west of barn, southeast corner sec. 1, T. 15 S., R. 21 E., Johnson County.

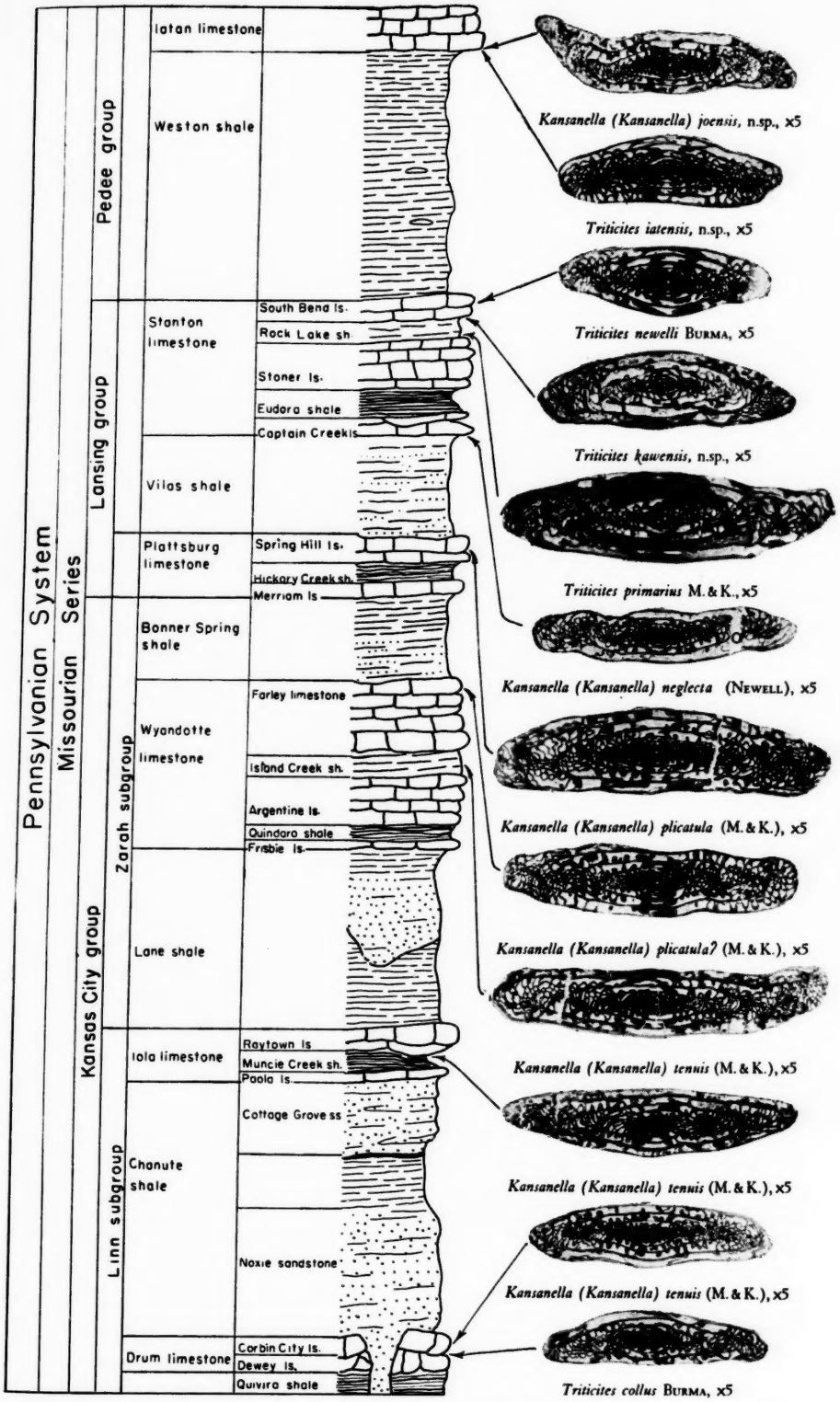
K-250. Spring Hill limestone; quarry at northwest corner of junction of old U. S. Highway 59 and Santa Fe Railroad, 5 miles southwest of Garnett.

K-253. Rock Lake shale; in shale above lower limestone, south bank of Little Sandy Creek, just east of bridge, west side NW¼, SW¼, sec. 31, T. 26 S., R. 15 E., Woodson County.

K-254. Wyandotte limestone; from 6 inch shale in road ditch on north side of road, 0.2 miles east of northwest corner sec. 19, T. 16 S., R. 25 E., Miami County.



TEXT-FIG. *1*—Diagram of lower Missourian rocks showing fusulinids. Vertical scale of 1 inch equals approximately 25 feet.



TEXT-FIG. 2—Diagram of upper Missourian rocks showing fusulinids. Vertical scale of 1 inch equals approximately 25 feet.

K-363-52. Bethany Falls limestone; in the railroad cut near the center of the south edge, NW¼, sec. 12, T. 19 S., R. 23 E., Miami County.

MISSOURI

M-2-52. Bethany Falls limestone; about three miles northeast of Martin City, NE¼, sec. 33, T. 48 N., R. 33 W., Jackson County.
M-3. Bethany Falls limestone; in shale zone in limestone of old quarry, SE¼, SW¼, sec. 17, T. 49 N., R. 32 W., Jackson County.
M-4. Bethany Falls limestone; on U. S. Highway 40, 0.7 miles east of Linwood Blvd., Kansas City.
M-8. Bethany Falls limestone; same locality as *M-4.*
M-18. Iatan limestone; south part of St. Joseph on east side of Highway 59.
M-20. Little Kaw limestone; first bluff on east side of road just north of Farley.
M-37. Iatan limestone; at top of east road-cut on Highway 71, 8.2 miles south of Faucett, and 3.7 miles south of the Buchanan County line.
M-39. Bethany Falls limestone; shale between limestone beds on walls of quarry opposite 3132 Raytown Road, Kansas City.
M-40. Hertha limestone, Sniabar limestone member; from about 8.4 feet above base of limestone, in a quarry on the eastern city limits of Kansas City, NE¼, SW¼, sec. 7, T. 49 N., R. 32 W.

NEBRASKA

N-5. Louisville, Nebraska.
N-6. Richfield Quarry, Richfield, Nebraska.

OKLAHOMA

O-4. Missourian limestone; 90 to 100 feet above the Avant limestone, road-cut on Oklahoma Highway 11, 2 miles north of Avant, SW¼, sec. 31, T. 24 N., R. 21 E., Osage County.

SYSTEMATIC PALEONTOLOGY

Genus OKETAELLA Thompson

OKETAELLA INFLATA Thompson & Lamerson, n. sp.

Pl. 21, fig. 1–8

The shell of *Oketaella inflata* is minute in size and inflated elliptical in shape; with broadly convex lateral surfaces, bluntly rounded polar ends, and about straight axis of coiling. Shells of two and a half to four volutions measure .53 to .92 mm. in length and .45 to .75 mm. in width, giving form ratios of 1.2 to 1.4. The first volution is almost spherical to staffelloid in shape and has a form ratio of about .8 to 1.1. That of the second and third volutions are about 1.2 and 1.4, and that of the fourth volution of one specimen is about 1.4.

The spirotheca is thin and seems composed of a tectum and lower layer with suggestion of perforations. The tectum and

---

EXPLANATION OF PLATE 21

All illustrations on this plate are unretouched photographs.

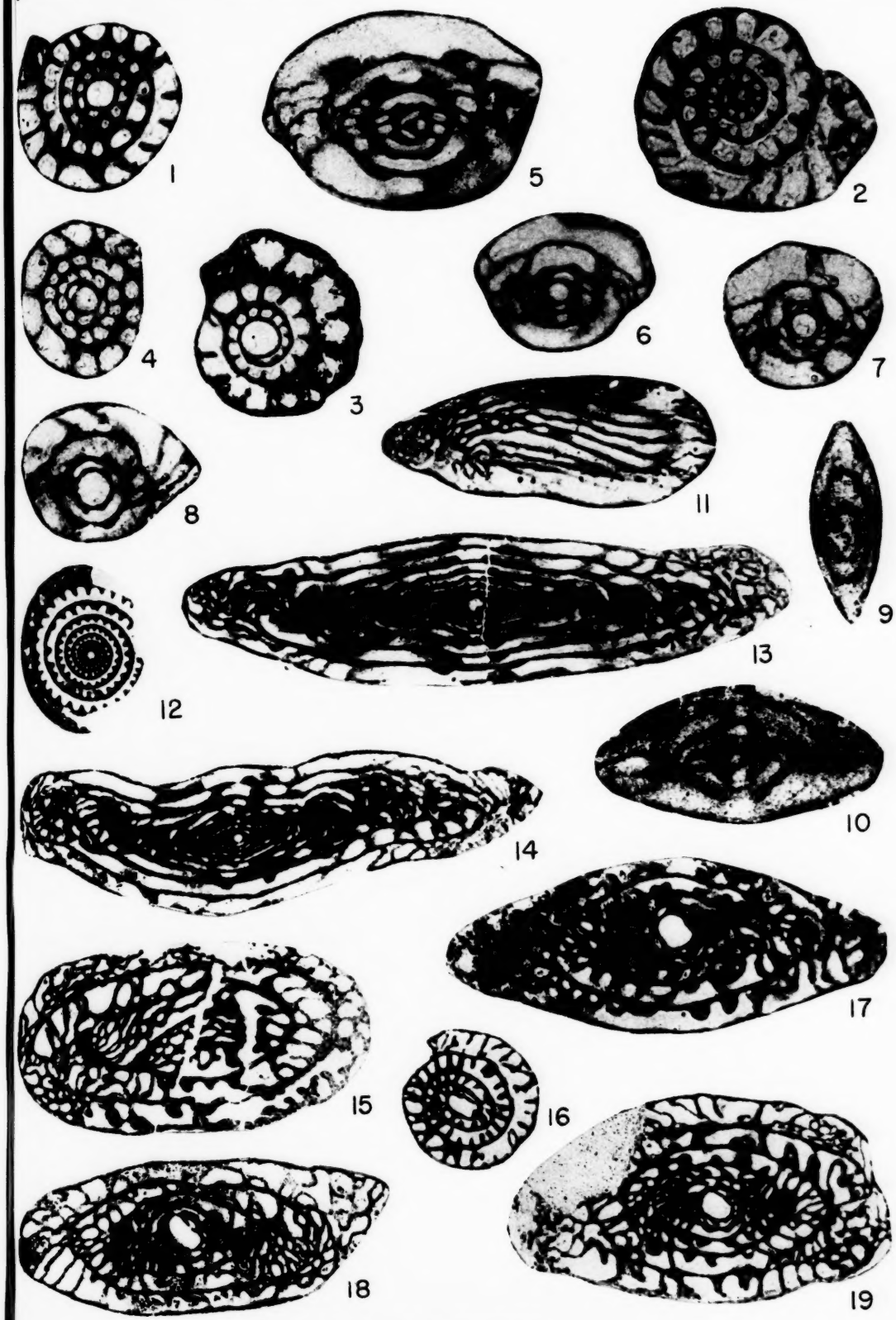
FIG. *1–8—Oketaella inflata* Thompson & Lamerson, n. sp. *1–4,* Sagittal sections of paratypes; *5,* axial section of the holotype; and *6–8,* axial sections of paratypes. All ×50 from the Sniabar limestone member of the Hertha limestone at Kansas City, Missouri (M-40). *1* to *8* are of specimens 7, 8, 5, 6, 4, 1, 2, and 3.

9—Millerella sp. Axial section from the Sniabar limestone member of the Hertha limestone at Kansas City, Missouri (M-40), ×100.

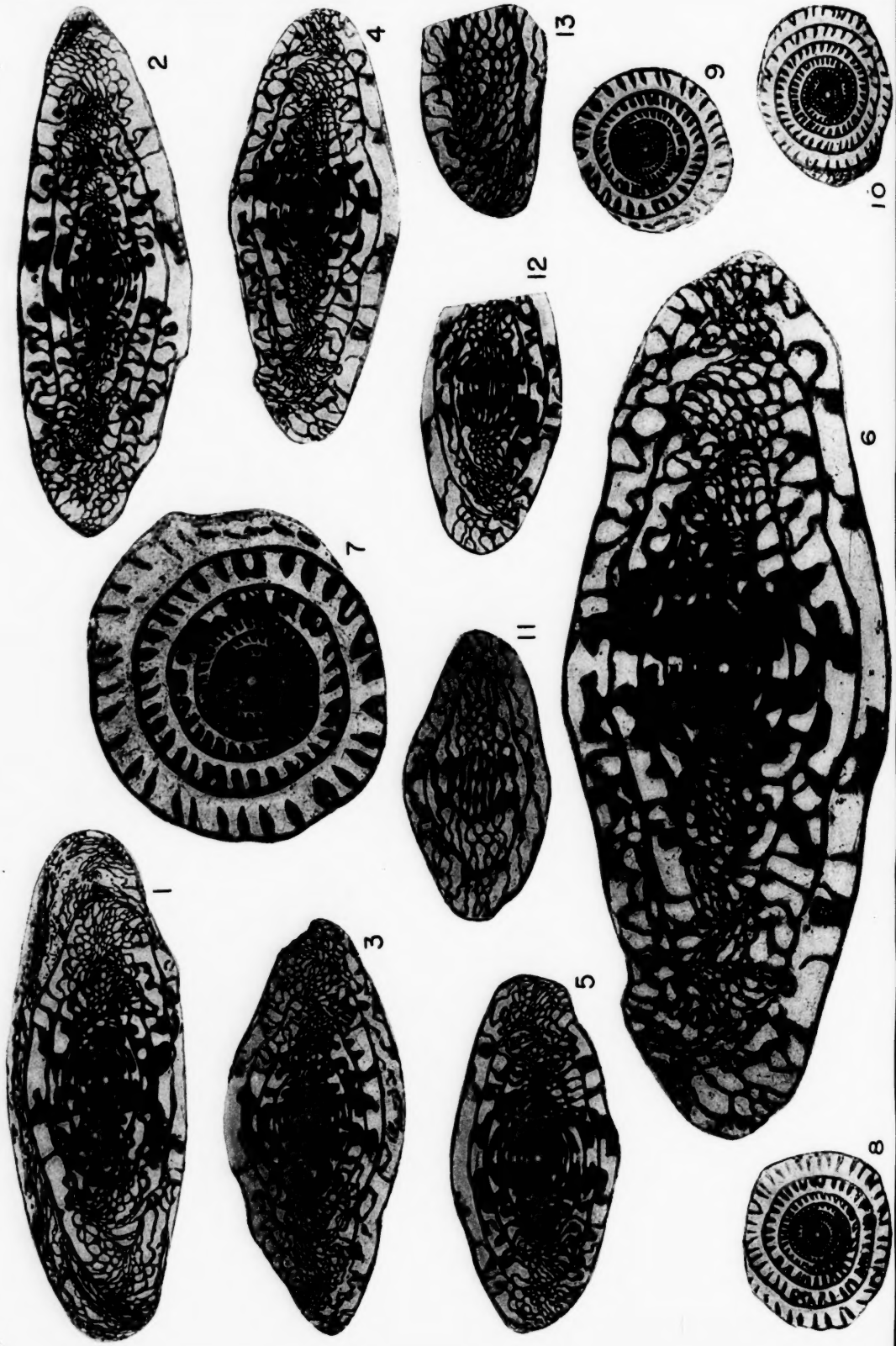
10—Schubertella sp. Axial section from the Sniabar limestone member of the Hertha limestone at Kansas City, Missouri (M-40), ×100.

11–14—Wedekindellina ultimata Newell & Keroher. *11,* Tangential section showing nature of septal fluting; *12,* sagittal section; and *13, 14,* axial sections; all ×20. *11* and *13* are of topotypes from the Bethany Falls limestone in Kansas City (M-3), and *12* and *14* are of specimens from the Bethany Falls near Kansas City (M-2-52).

15–19—Fusulina fallsensis Thompson, Verville & Lokke. *15,* Tangential section of a paratype; *16,* sagittal section of a paratype; *17,18,* axial sections of paratypes; and *19,* axial section of the holotype; all ×20. *15,17,* and *19* are from the Bethany Falls limestone south of Kansas City, Kansas (K-363-52), and the others are from the same limestone near Kansas City, Missouri (M-2-52).



M. L. Thompson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Measurements of *Oketaella inflata* Thompson & Lamerson, n. sp., in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions				Thickness of spirotheca			
					1	2	3	4	1	2	3	4
1	0.56	0.47	1.2	.085	.040	.089	.097	—	.005	.009	.011	—
2	0.53	0.45	1.2	.101	.033	.058	.118	—	.007	.010	.011	—
3	0.60	0.46	1.3	.133	.056	.076	—	—	—	—	—	—
4	0.92	0.64	1.4	—	.041	.061	.112	.142	.008	.013	.013	.022
5	—	0.59	—	.136	.050	.075	—	—	.007	.012	—	—
6	—	0.52	—	.108	.043	.051	.106	—	—	.007	.012	—
7	—	0.61	—	.112	.048	.060	.077	—	—	—	—	—
8	—	0.75	—	.083	.045	.061	.107	—	—	.011	—	—

Specimen	Form ratio of volutions				Septal count			Tunnel angle (degrees)			
	1	2	3	4	1	2	3	1	2	3	4
1	0.8	1.0	1.2	—	—	—	—	—	—	—	—
2	0.9	1.2	1.2	—	—	—	—	36	43	—	—
3	1.1	1.2	—	—	—	—	—	31	34	—	—
4	1.1	1.2	1.4	1.4	—	—	—	—	37	31	50
5	—	—	—	—	12	12	—	—	—	—	—
6	—	—	—	—	8	12	12	—	—	—	—
7	—	—	—	—	10	12	17	—	—	—	—
8	—	—	—	—	8	13	15	—	—	—	—

lower layer are about 12 mm. thick in the third volution. No alveoli are observed. In the tunnel areas the tops and bottoms of the spirotheca are covered by what resembles tectoria. The coverings may be continuations of the chomata.

The septa are relatively widely spaced and are below rather distinct external furrows. They are about normal to the shell surface and seem to be plane throughout the length of the shell, but there is a slight suggestion that they are wavy in the extreme ends of the shell. The septal counts of the first to the third volution of four specimens average 10, 12, and 15, respectively.

The proloculus is relatively large and has an outside diameter of 83 to 133 microns, averaging 108 microns for seven specimens. The chambers increase in height relatively rapidly but uniformly. Average heights of the chambers above the tunnel in the first to the fourth volution of eight specimens are 44, 66, 103, and 142 microns, respectively.

The tunnel is moderately high and has a path that seems about straight. Its angle is about 31 and 50 degrees in the third and fourth volutions. Chomata are heavy especially adjacent to septa where they extend up toward the tops of the chambers on both sides with slowly diminishing thickness. In the outer chambers they have steep tunnel margins and lower lateral slopes. They extend to the axial areas to give the appearance of light axial fillings.

Remarks.—Oketaella inflata resembles *O.*

EXPLANATION OF PLATE 22

All illustrations on this plate are unretouched photographs, and all are magnified ×10 except *6* and *7*, which are magnified ×20.

FIG. *1–13—Kansanella* (*Iowanella*) *winterensis* (Thompson, Verville & Lokke). *1*, Axial section of the holotype; *2–6*, axial sections of paratypes; *7–10*, sagittal sections of paratypes; and *11–13*, tangential sections of paratypes. Type species of the new subgenus *Iowanella*. All from the Winterset limestone member of the Drum limestone (I-44).

lenensis from the Lenapah limestone of Oklahoma and *O. oscurensis* from the basal Coane limestone of New Mexico more closely than other known species and can be distinguished from the former most easily by its shorter and more inflated shell and more loosely coiled shell. It can be distinguished from *O. oscurensis* by its wider tunnel, more blunt polar ends, and more highly convex lateral surfaces. Also, its chomata are more narrow and restricted.

Occurence.—*Oketaella inflata* is the first fusulinid to be described from the Sniabar limestone (Hertha limestone) of the northern midcontinent region. It was discovered by Paul Lamerson in numerous thin sections of the Sniabar at Kansas City, Missouri, where it is associated with an undescribed species of *Schubertella* and an undescribed species of *Millerella* (M-40).

Genus WEDEKINDELLINA
Dunbar & Henbest
WEDEKINDELLINA ULTIMATA
Newell & Keroher
Pl. 21, fig. 11–14

Wedekindellina ultimata NEWELL & KEROHER, 1937, Jour. Paleont., vol. 11, p. 700–705, pl. 93, fig. 1–9; THOMPSON, VERVILLE, & LOKKE, 1956, Jour. Paleont., vol. 30, p. 801–803, pl. 90, fig. 1–11, pl. 91, fig. 1–15.

The shell of *Wedekindellina ultimata* is highly elongate fusiform in shape; with sharply to bluntly pointed polar ends, straight to curving or irregular axis of coiling, inflated central area, and slightly concave to almost straight but low lateral slopes. Larger shells of seven to eight volutions measure 4.4 to 6.2 mm. long and 1.2 to 1.5 mm. wide, giving form ratios of 3.1 to 4.4. The first volution is almost round but the axes of later volutions become rapidly extended, and the form ratios of volutions increase rapidly to the fourth or fifth volution. Averages of the form ratios of the first to the eighth volution of seven specimens are 1.4, 1.9, 2.3, 2.9, 3.0, 3.2, 3.4, and 3.7, respectively. Many larger specimens develop a curved or irregular axis of coiling.

The proloculus is small and spherical in most specimens, measuring 75 to 127 microns in outside diameter and averaging 104 microns in nine specimens. Averages of the heights of the chambers above the tunnel in ten specimens are 36, 40, 56, 67, 86, 106, 121, and 140 microns, respectively. The chambers are lowest above the tunnel, and they increase in height slowly poleward and become highest near the polar ends.

The spirotheca is thin throughout the shell but is thickest above the tunnel. It is composed of the tectum and diaphanotheca and is covered above and below by rather thick layers of tectoria. The thick and broad chomata and heavy axial fillings which join the chomata in most volutions are difficult to distinguish from the tectoria. The proloculus wall is too thin to measure accurately. Averages of the combined thicknesses of tectum and diaphanotheca above the tunnel in the fourth to seventh volution of nine specimens are 13, 15, 16, and 19 microns, respectively.

The septa are closely spaced throughout the shell. They are plane across the central half of the shell and are fluted in the end quarters. However, the fluting forms closed chamberlets only in the extreme end zones. Averages of the septal counts of the first to the seventh volution of three specimens are 10, 17, 20, 22, 22, 24, and 28, respectively.

The tunnel is slightly more than half as high as the chambers and is moderately narrow. It expands in width very slowly to the fifth or sixth volution and has a path that is almost straight. Averages of the tunnel angle in the fourth to the eighth volution are 19, 23, 27, 33, and 27 degrees, respectively. The chomata are high and broad and have vertical to overhanging tunnel sides and low poleward slopes. They join with the axial filling in inner volutions without an obvious break, but in outer volutions of most specimens they are broad but are separated from the axial fillings. In an occasional specimen the axial fillings are continuous with the chomata even to the ultimate volution. Axial fillings are very heavy in typical specimens and completely fill most of the chambers in the axial areas of all volutions except the outer one to three volutions. They do not seem of exactly the same weight in all specimens even from the same locality but are invariably rather heavy at all places studied in Kansas, Missouri, and Iowa.

Remarks.—The above description is based on topotype specimens of *Wedekindellina ultimata* from the Bethany Falls limestone in Jackson County, Missouri, and in Miami

County, Kansas, both in the greater Kansas City area, and from the Bethany Falls near Winterset, Iowa. The specimens from the vicinity of Kansas City seem somewhat larger than those from Iowa but this may be more apparent than real. In general, the axial fillings in both localities are closely similar, and most of our axial sections from Iowa contain one less volution.

Specimens here referred to this species are very abundant in the Coane formation at many places in New Mexico and is one of the better key index fossils for this part of the stratigraphic section. In fact, it composes large percentages of the upper Coane limestones over wide areas. Numerous thin sections have been prepared of the New Mexico collections and many of them have been measured. In general, the New Mexico specimens are smaller than the types from Missouri and they may represent different subspecies.

Wedekindellina ultimata differs from *W. ardmorensis* Thompson, Verville & Lokke particularly by its more tightly coiled outer volution, more closely spaced outer septa, more dense axial fillings, and heavier chomata.

Wedekindellina ultimata and *W. ardmorensis* have axial fillings as in typical *Wedekindellina*, have wall structures as in the genotype species, have closely spaced septa as in the genotype, and have elongate slender shells with inflated central areas as in the genotype and in most other Desmoinesian typical species. They differ from the genotype particularly in their septal fluting developed in the polar regions. In this latter respect they resemble *Pseudofusulinella occidentalis* (Thompson & Wheeler), the genotype of *Pseudofusulinella*. However, the wall structure of the latter species seems different from that of the lower Missourian species.

Wedekindellina ultimata is very abundant over wide areas in central United States west of the Mississippi River to the New Mexico region. It seems restricted to the same general part of the stratigraphic section above the base of the Missourian and constitutes one of the very best of the index fossils for correlation of lower Missourian rocks.

Occurrence.—*Wedekindellina ultimata* has been observed at many places in the Bethany Falls limestone in Iowa (I-2, I-48), Missouri (M-3, M-4, M-8, M-39, M-2–52), and Kansas (K-33, K-363–52). At the localities M-2–52 and M-363–52 it is associated with common specimens of *Fusulina fallsensis*. Abundant specimens are also found in subsurface lower Missourian rocks of Texas and in the Coane formation exposed in many parts of New Mexico. It is restricted to the Coane formation and rocks of equivalent age in New Mexico and extreme west Texas. It is exceedingly abundant in the Sandia Mountains, Ladron Mountain area, Oscura Mountains, San Andres Mountains, Robledo Mountains, and Hueco Mountains.

Genus FUSULINA Fischer-de-Waldheim
FUSULINA FALLSENSIS Thompson, Verville, & Lokke
Pl. 21, fig. 15–19

Fusulina fallsensis THOMPSON, VERVILLE, & LOKKE, 1956, Jour. Paleont., vol. 30, p. 799–801, pl. 89, fig. 12–23.

The shell of *Fusulina fallsensis* is highly irregularly fusiform to subcylindrical in shape; with rounded to irregular polar ends, shifting to irregular axis of coiling, and irregular to convex lateral slopes. Larger shells contain four to five volutions and have an average form ratio of 2.4 for nine specimens. The holotype specimen of five volutions measures about 2.9 mm. long and 1.6 mm. wide, giving a form ratio of about 1.8. Another typical specimen of five volutions measures 3.5 mm. long and 1.6 mm. wide, giving a form ratio of 2.2. The averages of the form ratios of the first to the fifth volution of eight specimens are 1.3, 1.7, 2.0, 2.2, and 2.0, respectively. These average determinations of the form ratios have little significance, however, for no single specimen has ratios that correspond exactly with them. The shape of the shell of any given volution varies widely. For instance, the third volution of some specimens is elongate fusiform with sharply pointed polar ends, but the same volution of other specimens is inflated irregularly and is ellipsoidal in shape with broadly rounded polar ends.

The proloculus is abnormally large for the size of the shell, and it is highly irregular in shape. In some specimens it is spherical in

shape but in most specimens it is deeply depressed around the proloculus pore and very broadly convex on the opposite side. Its greatest diameter varies from 219 to 353 microns, averaging 257 microns for thirteen specimens. In general, the chambers are lowest immediately above the tunnel, but many of them are variable in height from pole to pole. The lateral surfaces turn into the polar ends rather sharply in outer volutions, resulting in blunt to rounded polar ends.

The spirotheca is thin and is composed of the tectum and the diaphanotheca, the latter of which shows a porous structure in some parts of the shell. The thicknesses of the tectum and diaphanotheca in the third and fourth volutions of the holotype specimen measure about 24 and 27 microns, respectively. The proloculus wall of this same specimen measures about 15 microns. Averages of the thicknesses of the tectum plus the diaphanotheca above the tunnel in the first to the fifth volution of twelve specimens, including the holotype, are 14, 18, 22, and 24 microns, respectively.

The septa are thin and are fluted throughout the length of the shell so as to form closed chamberlets above the tunnel. Closed chamberlets extend about three-fourths as high as the chambers immediately adjacent to the tunnel. The fluting is not uniform laterally along the septa or vertically up the septa. Averages of the septal counts of the first to the fourth volution of three specimens are 10, 19, 25, and 30, respectively.

The tunnel is narrow and its path is irregular. The irregular path of the tunnel corresponds to the irregularly shifting axis of coiling. In one specimen, the tunnel path in the first volution is almost parallel to the axes of outer volutions. Also, the width of the tunnel varies considerably for a given volution among different specimens. Although the tunnel angle is quite variable among different specimens, it averages about 28, 30, and 50 degrees in the third to the fifth volution, respectively, of eight specimens. Chomata deposits are heavy but are irregularly spread along the septa and spirotheca. Most volutions contain slightly asymmetrical chomata which are about a third as high as the chambers. Axial fillings completely fill chambers in the first two to three volutions in some specimens and only partly fill the chambers in extreme polar ends of outer volutions.

Remarks.—*Fusulina fallsensis* has one of the most highly irregularly shaped shells of any known species of the genus. The shell varies from an almost perfectly fusiform shape to a highly crooked shape. Also, the general shell volume varies considerably among different specimens. It can be distinguished from other species of the genus by its irregular shape, its loose and irregular shell coiling, its large and irregular proloculus, its discontinuous tectoria, its axial fillings, and its irregularly fluted septa. The general spirothecal structure of *Fusulina fallsensis* compares closely with that of *F. eximia* from the Cooper Creek limestone of Iowa and of *F. cylindrica* of the upper Moscovian of Russia. Both of these last two species are highly elongate subcylindrical in shape and are considerably larger in size. The proloculus of *F. eximia* is about spheri-

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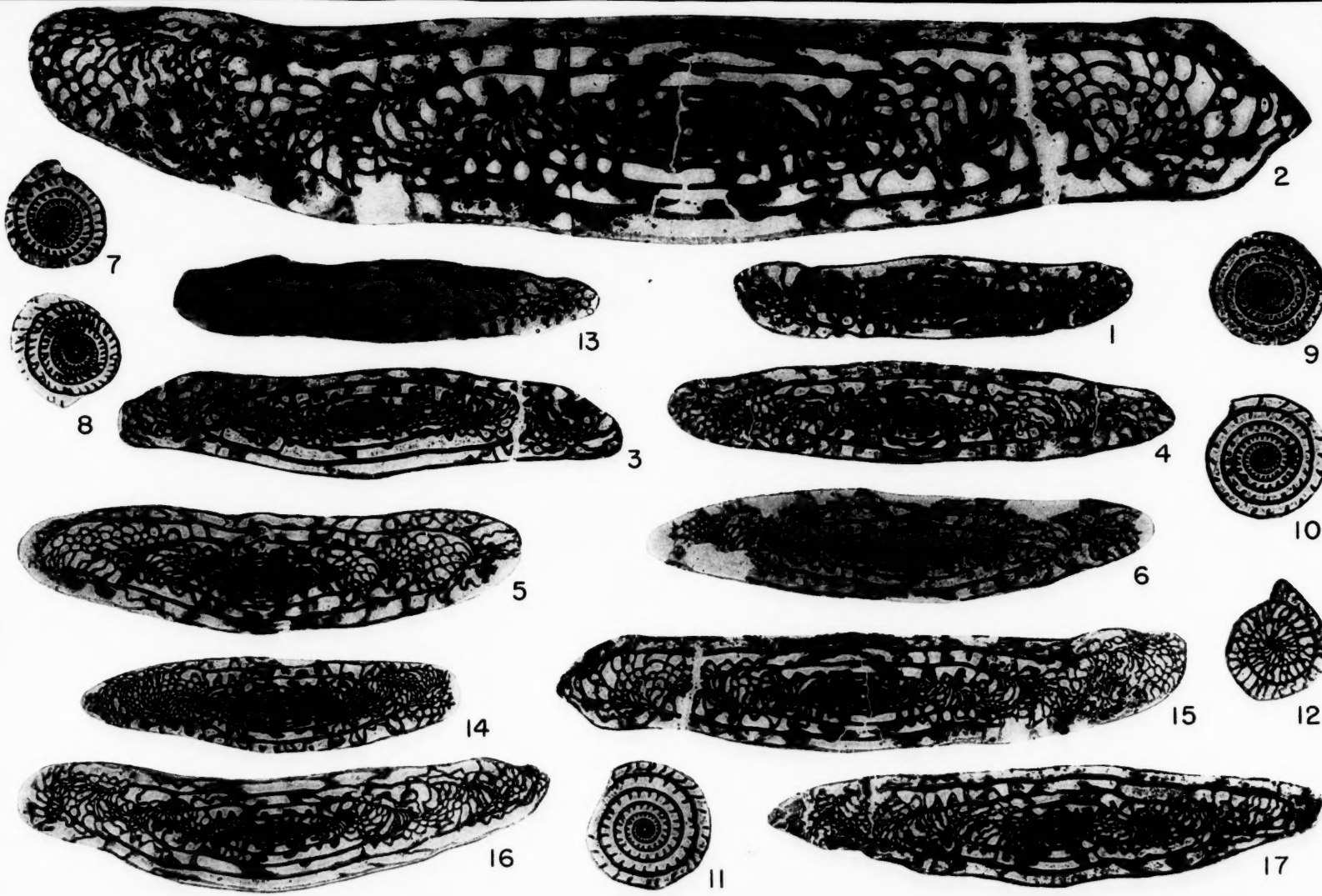
EXPLANATION OF PLATE 23

All illustrations on this plate are unretouched photographs, and all are magnified ×10 except *2*, which is magnified ×20.

FIG. *1–17*—*Kansanella* (*Kansanella*) *tenuis* (Merchant & Keroher). *1*, Axial section of the holotype; *2,3,4,15*, axial sections of topotypes; *5,6*, axial sections; *7,8*, sagittal sections; *9*, sagittal section of a paratype; *10*, sagittal section of a topotype; *11*, sagittal section; *12*, parallel section; *13*, tangential section of a paratype; and *14,16,17*, axial sections. *2–4,10*, and *15* are from a thin shale in the Wyandotte limestone of Miami County, Kansas (K-254). *5* is the holotype specimen of *Triticites caccus* Burma from the Argentine limestone of Iowa, and *6,7*, and *12* are topotype specimens of the same form (I-60). *8* and *14* are from the Dewey limestone (Cement City) of Iowa (I-54). *11,16*, and *17* are from the Iola limestone of Kansas (K-182). *1,2*(=*15*),*3,4,9*, and *10* are of specimens 1, 3, 5, 4, 2, and 7 of measurements (K-254 and types).



M. L. Thompson

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cal in shape and is minute in size. In contrast, the proloculus of *F. fallsensis* is large and is highly irregular in shape. *F. cylindrica* also has a large irregular proloculus. The early volutions of *F. eximia* are symmetrical with the outer volutions, but in contrast, the early volutions of both *F. fallsensis* and *F. cylindrica* are variable in their general attitude toward outer volutions.

Fusulina cylindrica has irregularly distributed axial fillings somewhat like that in *F. fallsensis*, but the fillings of the former are somewhat heavier. Also, *F. eximia* has very slight and discontinuous axial fillings. It is generally agreed that species like *F. cylindrica* are on one extreme end of the genus *Fusulina* and such lower Desmoinesian species like *F. prima* are on the other extreme near the earliest species of the genus. The great numbers of the species of the genus between rocks of lower Desmoinesian age and late Moscovian (probably early Missourian) are in a large part quite different from *F. cylindrica*, except that they have septal fluting throughout the length of their shells and a spirothecal structure somewhat alike. The genotype of *Quasifusulina*, *Fusulina longissima* Möller, actually has many more shell features similar to those of *F. cylindrica* than do the lower Desmoinesian species.

Due largely to a misinterpretation of shell features, Möller (1877) established the genus *Hemifusulina* in 1877. *H. bocki* Möller (*Fusulina minima* Schwellwien, 1908), the genotype, was not described until the following year. The type species of *Hemifusulina* is very closely similar to the lower Desmoinesian fusulinids now generally referred to *Fusulina*. Also, Galloway (1933) established the genus *Beedina* (with *Fusulinella girtyi* Dunbar & Condra as the genotype) for the Desmoinesian type of fusulinid now referred to *Fusulina*.

If the lower Desmoinesian fusulinids now commonly referred to *Fusulina* are to be separated generically from *F. cylindrica*, *Hemifusulina* is the earliest valid genus established for them and it has priority over the name *Beedina* proposed by Galloway. Both *Hemifusulina* and *Beedina* are here considered synonyms of *Fusulina*. However, should either or both be resurrected for the Desmoinesian species, *F. fallsensis* should still be referred to the genus *Fusulina;* it is a typical form of the genus.

Occurrence.—*Fusulina fallsensis* is rather scarce in association with abundant *Wedekindellina ultimata* in the Bethany Falls limestone and in the neighborhood of Kansas City, Missouri, and Kansas City, Kansas. The above description is based on specimens from the Bethany Falls in Miami County, Kansas (K-363–52) and Jackson County, Missouri (M-2–52).

Genus KANSANELLA Thompson, n. gen.

Type species: *Kansanella (Kansanella) joensis* Thompson, n. sp.

Diagnosis.—The shell of *Kansanella* is moderately large and is inflated fusiform to highly elongate fusiform or irregularly subcylindrical in shape; with convex to concave or irregular lateral slopes, almost straight to shifting axis of coiling, and pointed to rounded polar ends. Specimens contain up to about ten volutions at maturity and are up to 10 mm. long and 2.8 mm. wide and have form ratios as great as 5 or 6. The type species of eight and a half volutions is slightly less than 2 mm. wide and about 9 mm. long. The type species of the new subgenus *Iowanella* is up to 8.0 mm. long and 2.8 mm. wide. In general, most

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EXPLANATION OF PLATE 24

All illustrations on this plate are unretouched photographs, and all are magnified ×10 except *1*, which is ×20.

FIG. *1–13*—*Kansanella (Kansanella) plicatula* (Merchant & Keroher). *1*, Axial section of the holotype; *2,3*, tangential sections of paratypes; *4,5,7*, sagittal sections of topotypes; *6*, sagittal section of a paratype; *8,9*, parallel sections of topotypes; *10–12*, axial sections of topotypes; and *13*, axial section. All are from the Plattsburg limestone of Kansas (K-250) except for *13*, which is from the Farley limestone of Kansas (K-179), *1,4–7*, and *10–12* are of specimens 5, 8, 10, 6, 9, 4, 1, and 2 of measurements.

species have shells that vary considerably in shape from those with a straight axis of coiling to those with arcuate or highly irregular axes of coiling. The proloculus is small and spherical in shape, and the shell expands gradually but slowly. The spirotheca is thin for the size of the shell, has near the same thickness in the central half of the shell length, is composed of the tectum and finely alveolar keriotheca, is thin in the first volutions, gradually increases in thickness to maturity, and attains a thickness as great as near 45 microns in the eighth volution of the type species. In some representatives it is as thick as 70 microns in the eighth volution. The septa are moderately widely spaced and are composed of thin pycnotheca. They are fluted throughout the length of the shell and completely to the tops of the chambers. However, the fluting is non-uniform from septum to septum, laterally along a given septum, and vertically up a given septum. The tunnel is wide, and its path is almost straight. Chomata are present throughout the shell and extend along the septa and walls as irregular deposits for considerable distances toward the poles. In the first four or five volutions the chomata are high and extend completely to the polar ends and join with axial fillings that almost completely fill the chambers. Axial fillings occur in most, if not all, species but are better developed in the inner volutions.

Remarks.—Until fairly recent years all described Upper Pennsylvanian American larger fusulinids were assigned to the genus *Triticites* Girty. However, in 1934 Newell described a form as *Triticites osagensis* from Missourian rocks in Oklahoma that has many features quite different from typical *Triticites* that are closely similar to the type species *T. secalicus* (Say). Also, a number of workers have since described fusulinids somewhat like *T. osagensis* from rocks throughout most of the Missourian Series, such as *T. neglectus* Newell (1934) from the Captain Creek limestone, *T. tenuis* Merchant & Keroher (1939) from the Wyandotte limestone, *T. plicatulus* Merchant & Keroher (1939) from the Spring Hill limestone member of the Plattsburg formation, and *T. winterensis* Thompson, Verville, & Lokke (1956) from the Winterset limestone.

The very abundant fusulinid *Dunbarinella ervinensis* Thompson of the lower Virgilian of Oklahoma was made the type species of *Dunbarinella* Thompson in 1942. This form is characterized by a moderately large shell, heavy axial filling, moderately intense and uniform septal fluting, and a spirotheca somewhat like that of *Triticites*. This constitutes the third group of larger fusulinids that has been found in Upper Pennsylvanian rocks in the midcontinent region.

During the present study of all fusulinids of the Upper Pennsylvanian of the northern midcontinent region, the general group of fusulinids like *Triticites osagensis* Newell and *T. neglectus* Newell has been found in practically every major limestone unit from the Winterset limestone up to and including the Lecompton limestone formation in the Shawnee group of the Virgilian. In addition to the five species formerly described and listed above, this group is represented by great numbers of specimens in the Iatan limestone, throughout most major limestone units of the Oread limestone of the lower Shawnee group, and in the Lecompton limestone formation of the Shawnee group. All of these are here recognized as belonging to the new genus described above as *Kansanella*, with *K.* (*K.*) *joensis*, new species, as genotype. The form *T. winterensis* is selected as the type species of the subgenus of *Kansanella* described below as *Iowanella*. The form *K.* (*K.*) *joensis* is the subgenotype of the typical new subgenus *Kansanella*. The genus *Kansanella* has a stratigraphic range from the Winterset limestone of the Missourian Series up to the Shawnee group of the Virgilian Series and is represented in Missourian rocks of the northern midcontinent region by the species *K.* (*I.*) *winterensis*, *K.* (*K.*) *tenuis*, *K.* (*K.*) *neglecta*, *K.* (*K.*) *plicatula*, and *K.* (*K.*) *joensis*. Also, two undescribed species of this biologic unit are abundant in the Shawnee group of the lower Virgilian. Throughout this stratigraphic interval specimens of *Kansanella* compose the most abundant of the midcontinent fusulinids. However, unquestioned representatives of this genus and its subgenera have not been described from outside the midcontinent region. The only reference to possible species of this general group

were those referred with question to *Triticites neglectus* and *T. plicatulus* from the Oquirrh formation of Utah by Thompson, Verville, & Bissell (1950).

Species of *Kansanella* have been referred to *Triticites* on several occasions, but most students have recognized that they are not closely similar to *T. secalicus* (Say), the type species of *Triticites*. They differ from *Triticites* by their irregularly elongate and slender shells, intense but highly irregular septal fluting, axial fillings, irregular lateral slopes, and irregular axes of coiling. Also, the spirotheca of *Kansanella* increases in thickness much more slowly with increase in the size of the shell. The pronounced but irregular septal fluting alone is sufficient to distinguish *Kansanella* from *Triticites*.

Kansanella can be distinguished from *Schwagerina* by its distinct irregularity of septal fluting, less regular and uniform shell, and considerably thinner spirotheca in comparison to shell size. The laterally spreading deposits of the chomata so characteristic of *Kansanella* are totally lacking in typical *Triticites* and *Schwagerina*.

Subgenus IOWANELLA Thompson, n. subgen.

Type species: *Triticites winterensis* THOMPSON, VERVILLE, & LOKKE, 1956.

Diagnosis.—The shell of the new subgenus *Iowanella* is moderately large and inflated fusiform in shape; with an inflated central area, sharply to bluntly pointed polar ends, and slightly convex to concave lateral slopes. The type species has up to eight volutions and measures up to 2.8 mm. wide and 8.0 mm. long, giving a form ratio near 3.0. The shell changes with growth from a short inflated and elliptical shape in the first volution with a form ratio slightly greater than unit value to an elongate fusiform shape at maturity. All volutions are almost perfectly symmetrical. The proloculus is small and spherical in shape, and the shell expands slowly and uniformly. The spirotheca is thin and is composed of the tectum and a thin alveolar keriotheca. However, the keriotheca is very thin in inner volutions where it seems structureless in most specimens. The proloculus wall is relatively thick and is structureless except for the proloculus pore. The septa are closely spaced and are composed of a distinct pycnotheca. They are fluted throughout the length of the shell, but the fluting is highly irregular laterally along the septa and vertically up the septa. In fact, the general pattern of fluting seems to vary from septum to septum without a uniform pattern. The fluting effects the septa throughout their height. Septal pores are abundant but seem more closely spaced in the axial areas. The tunnel is narrow and high and has a straight to slightly shifting path. The chomata are high and broad and have steep to overhanging tunnel sides and steep to low poleward slopes. They extend along the septa and spirotheca to polar regions in the inner four or five volutions and a third to half the distance to the poles in outer volutions. They almost completely fill chambers adjacent to the tunnel and leave a small lateral opening at the tops of the chambers.

Remarks.—*Iowanella* resembles in several respects the typical subgenus *Kansanella* described above and is considered closely related to it. It can be distinguished from that subgenus by a shorter and more inflated shell, more massive chomata, and more uniform lateral slopes and axis of coiling.

The new subgenus *Iowanella* can be distinguished from *Triticites* by its irregularly and broadly fluted septa throughout the length of the shell, its abnormally broad and massive chomata, its relatively thin spirotheca in comparison to the size of the shell, and its axial fillings. The subgenotype from the Winterset limestone member of the Dennis limestone and from the Drum limestone is the only known species.

KANSANELLA (IOWANELLA) WINTERENSIS (Thompson, Verville, & Lokke)

Pl. 22, fig. 1–13

Triticites winterensis THOMPSON, VERVILLE, & LOKKE, 1956, Jour. Paleont., vol. 30, p. 807–810, pl. 93, fig. 1–13.

The shell of *Kansanella* (*Iowanella*) *winterensis* is moderately large in size and inflated fusiform in shape; with slightly inflated central area, bluntly rounded polar ends, slightly convex, almost straight to slightly concave or irregular lateral slopes, and curving to slightly irregular axis of

coiling. Mature specimens of seven to eight and a half volutions are 2.4 to 2.8 mm. wide and 6.0 to 8.0 mm. long, giving form ratios of 2.3 and 3.1. The first four to six volutions are ellipsoidal in profile, but beyond the sixth volution the polar ends are slightly more extended. Averages of the form ratios of the first to the seventh volution of six specimens are 1.4, 1.7, 1.8, 1.9, 2.1, 2.3, and 2.3, respectively.

The proloculus is small in size and spherical in shape. Its outside diameter measures 125 to 164 microns and averages 150 microns for seven specimens. The shell is tightly coiling, and the chambers increase in height about uniformly. Averages of the heights of the chambers in the first to the seventh volution of nine specimens are 41, 67, 91, 130, 185, 260, 303, and 330 microns, respectively. The chambers are of near the same height throughout their width in the inner six or seven volutions, but they increase in height rather sharply in the polar areas of the outer three to four volutions.

The spirotheca is thin in comparison to the size of the shell. It is coarsely alveolar in the outer volutions and shows distinct alveoli in the first volution of some specimens. However, in the first few volutions of some specimens it seems composed of the tectum and a lower structureless layer. Averages of the thicknesses of the spirotheca above the tunnel in the third to the eighth volution of nine specimens are 21, 25, 36, 49, 58, and 61 microns, respectively. The proloculus wall is thick and measures about 18 microns.

The septa are thin and are closely spaced. Averages of the septal counts of the first to the eighth volution of three specimens are 11, 19, 23, 28, 32, 36, 38, and 43, respectively. The septa are fluted throughout the length of the shell, and the fluting forms closed chamberlets even above the tunnel. However, the fluting seems irregularly spaced along the septa. The fluting in the outer volutions of larger specimens seems similar in nature to that found in the subgenus *Acervoschwagerina*.

The tunnel is narrow, and its path is straight to slightly irregular. The tunnel angle averages 17, 20, 23, 25, 32, and 26 degrees, respectively, in the third to the eighth volution. The chomata are high and broad and have almost flat upper surfaces, steep to overhanging tunnel sides, and steep poleward slopes. In the inner five to six volutions the chomata extend to the polar ends, and they extend almost to the poles in the outer volutions. They reach the tops of the chambers adjacent to the septa and only a minute circular lateral opening is left above the chomata near the center of the chambers. The chomata extend across the floor of the tunnel in most volutions and coat the ends of the septa near the tunnel to give them a pendant shape.

Remarks.—Kansanella (Iowanella) winterensis bears little resemblance to other fusulinids, such as *Triticites ohioensis*, found in lower Missourian rocks. It differs from the latter especially by its larger shell, its more highly fluted septa, and its much more massive and more spreading chomata. In fact, *K. (I.) winterensis* has the most massive chomata of any species of Upper Pennsylvanian fusulinids. Also, it differs from Pennsylvanian forms of *Triticites* by its relatively thin spirotheca in comparison to the size of its shell.

It is not considered that *Kansanella (Iowanella) winterensis* was derived from a stock like most *Triticites* found in the lower part of American Missourian rocks. Furthermore, it is not considered to be ancestral to presently known later forms in America such as typical species *Kansanella (Kansanella)*. However, a common ancestor may have given rise to *K. (I.) winterensis* and the numerous species and varieties which have been described from higher in the stratigraphic section and are here referred to *Kansanella*, such as *K. (K.) osagensis* (Newell), *K. (K.) neglectus* (Newell), and others. All of these later species are very long and slender and they have irregularly and highly fluted septa throughout the length of their shells, and some of the group, such as *K. (K.) joensis* from the Iatan and lower Virgilian undescribed forms, have heavy axial fillings. However, if *K. (I.) winterensis* is related to these later species the relationship is considered to be distant.

Occurrence.—Kansanella (Iowanella) winterensis is abundant in the middle part of the Winterset limestone at Winterset, Iowa (I-44) where it is associated with common specimens of *Triticites ohioensis* and is less

common in the upper part (I-50) and the lower part (I-53) of the same limestone where it is associated with abundant specimens of *T. ohioensis*. Rare specimens occur in the Drum limestone of Iowa (I-54) in association with *Triticites collus*.

Subgenus KANSANELLA Thompson, n. subgen.

Type species: *Kansanella* (*Kansanella*) *joensis*, n. sp.

Diagnosis.—The shell of the new subgenus *Kansanella* is moderately large and is highly elongate subcylindrical to irregular in shape; with irregular to straight or convex lateral slopes, straight to irregular axis of coiling, and rounded to bluntly pointed polar ends. Larger mature shells up to ten volutions measure up to 10.3 mm. long and 2.6 mm. wide, giving form ratios as great as 6. Most species of the subgenus have shells that are fusiform in shape with a straight axis of coiling in the inner four to five volutions and with pointed polar ends, but the axes of outer volutions become more irregular and shifting in position and the general shape of the shell may become irregular in shape. The proloculus is small and spherical in shape and the shell expands slowly but about uniformly. The spirotheca is thin and is composed of the tectum and a thin keriotheca. The keriotheca attains a thickness of 47 to about 70 microns in the seventh volution of described species. The proloculus wall is moderately thick and structureless. The septa are thin and composed of a thin pycnotheca. They are irregularly fluted throughout the length of the shell and up the septa to the top of the chambers. The fluting seems non-uniform from septum to septum. The tunnel is narrow in inner volutions and becomes moderately wide in outer volutions. Chomata are developed throughout the shell and are broad and highly asymmetrical in inner volutions and more nearly symmetrical in outer volutions. They extend to the polar regions in inner volutions and spread along the septa and spirotheca in outer volutions for considerable distances toward the poles. Axial fillings are developed in the extreme polar regions of most if not all species, but they are thin and somewhat discontinuous.

Remarks.—The group of fusulinids here referred to the subgenus *Kansanella* are exceedingly abundant in the midcontinent region from the Iola limestone, and perhaps as low as the Drum limestone, in the Missourian up into the lower Virgilian. Several species have been described previously and referred to the genus *Triticites*. However, typical forms of *Triticites* are more nearly symmetrical in general shell growth, they have more nearly symmetrical chomata, much less intensely and more uniformly fluted septa, thicker spirotheca compared to shell size, and have a total lack of axial fillings. The subgenus *Kansanella* can be distinguished from the new subgenus *Iowanella* by its more highly elongate and irregular slender shell, less massive chomata, and seemingly more widely spaced septa.

KANSANELLA (KANSANELLA) JOENSIS Thompson, n. sp.
Pl. 25, fig. 1; Pl. 26, fig. 1–11

The shell of *Kansanella* (*Kansanella*) *joensis* is of medium size and highly elongate fusiform to subcylindrical in shape; with bluntly to acutely pointed polar ends, irregular to highly crooked axis of coiling and subparallel to irregular or slightly inclined lateral surfaces. Larger shells of seven to nine volutions are 8.0 to 9.0 mm. long and 1.6 to 1.9 mm. wide, giving form ratios of about 4.4 to 5.0. The shape of the first four to five volutions is somewhat inflated fusiform with acutely pointed poles, but from the sixth volution to maturity the polar ends elongate rapidly and gradually results in a more nearly cylindrical shape at maturity. Averages of the form ratios of the first to the ninth volution of three specimens are 1.4, 1.9, 2.3, 2.4, 3.1, 3.6, 4.4, and 4.8, respectively.

The proloculus is minute in size and has an outside diameter of 57 to 97 microns, averaging 82 microns for six specimens. The shell is tightly coiled in the inner four to five volutions and becomes only slightly more loosely coiled in outer volutions. The general height of the chambers is less immediately above the tunnel than it is immediately poleward, but some specimens have slightly higher chambers above the tunnel than immediately lateral from the tunnel. The outer volution of all mature specimens

has chambers which become markedly higher in the near polar areas. Averages of the heights of the chambers above the tunnel in the first to the eighth volution of six specimens are 27, 34, 49, 73, 93, 146, 188, and 225 microns, respectively.

The spirotheca is thin and is composed of the tectum and a thin keriotheca. It is coated with secondary deposits throughout the length of the shell, probably extensions of chomata deposits, and gives it the impression in some places of a spirotheca with three layers, the lower of which is more transparent with faint alveoli, the middle of which is the tectum, and the upper of which is only slightly less dense than the tectum and is highly variable in thickness from the tunnel towards the poles. The variable points of intersection of a given chamber with a thin section in such a highly irregular shell probably shows many different parts of a given chamber throughout the length of the shell and results in observed variability in wall thickness. Averages of the thicknesses of the spirotheca in the fourth to the eighth volution of six specimens are 14, 21, 33, 39, and 46 microns, respectively. Averages of the thicknesses of the spirotheca in the middle of the chambers of the fifth to the eighth volution in three sagittal sections are 23, 46, 42, and 46 microns, respectively.

The septa are closely spaced and are moderately thick. They are composed of a thick and distinct pycnotheca. Averages of the septal counts of the first to the eighth volution of three specimens are 11, 18, 21, 23, 25, 30, 29, and 32, respectively. The septa are highly and irregularly fluted throughout the length of the shell so as to

Measurements of *Kansanella* (*Kansanella*) *joensis*, n. sp., in mm. (M-37)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							
					1	2	3	4	5	6	7	8
1	8.3	1.7	4.9	.057	.028	.023	.038	.042	.068	.097	.137	.202
2	8.4	1.8	4.7	.085	.024	.045	.054	.078	.110	.148	.186	—
3	9.1	—	—	.084	.024	.031	.038	.057	.071	.130	.137	—
4	—	2.0	—	.073	.024	.033	.044	.073	.082	.137	.171	.248
5	—	—	—	.099	.026	.038	.071	.110	.122	.193	.231	—
6	—	—	—	.097	.038	.037	.052	.077	.124	.174	.264	—

Specimen	Form ratio of volutions								Thickness of spirotheca							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	1.3	1.5	1.8	2.3	2.9	3.7	4.9	5.0	—	—	.009	.012	.019	.016	.026	.045
2	1.6	2.0	2.1	2.2	3.4	4.3	4.4	—	—	—	—	.016	.016	.024	—	—
3	1.4	2.1	3.0	2.6	2.9	2.8	3.8	—	—	—	—	—	—	.035	.042	—
4	1.4	1.9	2.3	2.4	3.1	3.6	4.4	—	—	—	—	—	.012	—	.037	.047
5	—	—	—	—	—	—	—	—	—	—	—	—	.037	.049	.046	—
6	—	—	—	—	—	—	—	—	—	—	—	—	.019	.042	.045	—

Specimen	Septal count								Tunnel angle (degrees)							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	—	—	—	—	—	—	—	—	—	—	—	17	22	24	35	36
2	—	—	—	—	—	—	—	—	—	—	18	22	21	37	38	34
3	—	—	—	—	—	—	—	—	—	—	16	18	24	27	35	37
4	11	18	21	22	25	31	29	32	—	—	—	—	—	—	—	—
5	12	20	21	24	24	31	30	—	—	—	—	—	—	—	—	—
6	10	17	20	22	25	27	—	—	—	—	—	—	—	—	—	—

form closed chamberlets above the tunnel. However, since the shell is so highly irregular, axial sections intersect the septa so irregularly that the true nature of the septal fluting cannot be determined exactly.

The tunnel path is almost straight and it is moderately narrow. Averages of the tunnel angle of the third to the eighth volution of three specimens are 17, 19, 22, 29, 36, and 35 degrees, respectively. The chomata are about two-thirds as high as the chambers, and they have steep to overhanging tunnel sides and low lateral slopes in inner volutions but steep lateral slopes in outer volutions. In the first four to five volutions the chomata extend to the polar ends. However, deposits comparable in density to that of the chomata coat the tops of the spirotheca and sides of the septa completely to the polar ends throughout most of the shell. These deposits about half fill the chamber in the tunnel area of the first five or six volutions and are thin in outer volutions.

Remarks.—Kansanella (*Kansanella*) *joensis* resembles *K.* (*K.*) *neglecta* more closely than other forms of this subgenus and can be distinguished from it perhaps more easily by its heavier axial fillings, more intensely fluted septa, more narrow tunnel angle, and more massive chomata in inner volutions.

Occurrence.—Kansanella (*Kansanella*) *joensis* is abundant in the Iatan limestone at St. Joseph, Missouri, and at numerous places south and southeasterly from St. Joseph. The above description is based on specimens from St. Joseph (M-18) and from along Highway 71 southeast of St. Joseph (M-37). It is associated with less abundant specimens of *Triticites iatensis*, n. sp.

KANSANELLA (KANSANELLA) TENUIS
(Merchant & Keroher)
Pl. 23, fig. 1–17

Triticites tenuis MERCHANT & KEROHER, 1939, Jour. Paleont., vol. 13, p. 604–606, pl. 69, fig. 1–3.
Triticites caccus BURMA, 1942, Jour. Paleont., vol. 16, p. 744–745, pl. 118, fig. 4,5.

The shell of *Kansanella* (*Kansanella*) *tenuis* is highly elongate and irregularly subcylindrical in shape; with irregular to broadly arched axis of coiling, bluntly pointed to narrowly rounded polar ends, and subparallel to irregular or low lateral slopes. Larger shells of six to eight volutions are 7.8 to 10.1 mm. long and 1.4 to 2.0 mm. wide, giving form ratios of 4.3 to 5.2. The holotype specimen, a submature individual, is 6.6 mm. long and 1.4 mm. wide, giving a form ratio of 4.7. The holotype specimen of *Triticites caccus* Burma, here considered synonymous with *K.* (*K.*) *tenuis*, has seven and a half volutions and is about 8.0 mm. long and 2.0 mm. wide. The first two volutions have blunt polar ends and strongly convex lateral surfaces, but beyond the second volution the shell rapidly elongates and develops first sharp polar ends and then rounded to bluntly angular polar ends at maturity. The averages of the form ratios of the first to the eighth volution of five specimens, including the holotype, are 2.0, 2.3, 2.5, 3.2, 4.0, 4.5, and 4.8, respectively. Those of the holotype specimen are 2.3, 2.5, 2.7, 3.1, 4.5, and 4.7 for the first to the sixth volution. The holotype specimen and six topotype specimens of *T. caccus* have average form ratios of 1.7, 2.1, 2.5, 2.9, 3.6, 3.9, 4.2, and 4.2, respectively, for the first eight volutions.

The proloculus is of medium size and has an outside diameter of 81 to 116 microns, averaging 95 microns for nine specimens. Average heights of the first to the seventh volution of nine specimens are 37, 54, 81, 132, 181, 220, and 229 microns, respectively. The height of the chambers is about uniform in the central half of the shell, but it increases gradually to near the poles in the outer four to five volutions where it heightens rapidly.

The spirotheca is of moderate thickness and its keriotheca contains coarse alveoli. It becomes thickest in the next to last two volutions, but is thinner in the final volution than in the penultimate volution. Averages of the thicknesses of the spirotheca in the second to the seventh volution of nine specimens are 13, 18, 28, 46, 60, and 64 microns, respectively.

The septa are widely spaced. Averages of the septal count of the first to the seventh volution of four specimens are 11, 16, 18, 22, 22, 25, and 24, respectively. The septa are very irregularly but highly fluted throughout most of the shell and form

Measurements of *Kansanella* (*Kansanella*) *tenuis* (K-254), in mm.
Specimen 1 is the holotype

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						
					1	2	3	4	5	6	7
1	6.6	1.4	4.7	.090	.029	.035	.060	.102	.161	.192	—
2	—	1.9	—	.081	.033	.045	.053	.104	.137	.181	.221
3	10.1	2.0	5.0	.109	.046	.062	.081	.136	.201	.278	—
4	8.3	1.6	5.2	.095	.038	.066	.095	.159	.190	.197	—
5	7.8	1.8	4.3	.070	.038	.044	.079	.119	.172	.242	.260
6	8.1	1.6	5.1	.101	.036	.051	.083	.124	.190	.210	.200
7	—	2.0	—	.101	.031	.057	.087	.128	.181	.208	.239
8	—	1.8	—	.090	.034	.050	.079	.132	.158	.217	.226
9	—	1.8	—	.116	.055	.076	.108	.181	.238	.257	—

Specimen	Septal count							Tunnel angle (Degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	—	—	—	—	—	—	—	—	22	33	39	53	—
2	11	14	17	21	17	22	25	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	21	34	54	58	—
4	—	—	—	—	—	—	—	—	—	21	29	41	69	—
5	—	—	—	—	—	—	—	—	—	18	33	36	45	—
6	—	—	—	—	—	—	—	—	—	23	31	38	46	47
7	12	17	20	22	24	22	20	—	—	—	—	—	—	—
8	11	15	16	20	21	26	26	—	—	—	—	—	—	—
9	11	18	21	26	28	29	—	—	—	—	—	—	—	—

Specimen	Form ratio of volutions							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	2.3	2.5	2.7	3.1	4.5	4.7	—	—	—	.014	.022	.041	.053	—
2	—	—	—	—	—	—	—	.010	.015	.013	.023	.031	.055	.070
3	2.1	2.4	2.6	3.7	4.3	5.3	5.0	—	.016	.022	.024	.053	.061	—
4	2.1	2.3	2.6	3.6	4.7	5.0	—	—	.010	.019	.031	.054	.062	—
5	1.6	1.9	2.1	2.7	2.7	3.6	4.3	—	.011	.020	.027	.052	.078	.075
6	2.0	2.3	2.7	3.1	3.6	4.0	5.1	—	.014	.021	.028	.034	.050	—
7	—	—	—	—	—	—	—	—	—	.019	.031	.046	.064	.060
8	—	—	—	—	—	—	—	—	.010	.019	.038	.045	.054	.050
9	—	—	—	—	—	—	—	—	—	.015	.029	.060	.058	—

closed chamberlets even above the tunnel. However, in general, the fluting does not bring the septa in contact above the tunnel. The fluting seems to vary considerably in intensity and in height along the septa.

The tunnel is high and broad, and its path is about straight. Averages of the tunnel angle in the third to the seventh volution of five specimens are 21, 32, 42, 54, and 47 degrees, respectively. The chomata are narrow and highly asymmetrical. They are more than half as high as the chambers and have steep to vertical tunnel sides and steep but sloping lateral surfaces.

Remarks.—Two names were proposed for specimens here referred to *Kansanella* (*Kansanella*) *tenuis* from the Wyandotte limestone of Iowa and Kansas. One of these, *K.* (*K.*) *tenuis*, was proposed by Merchant & Keroher for specimens from the Island Creek? shale member of Miami County, Kansas, and the other, *K.* (*K.*) *caccus*, was proposed by Burma for specimens from a thin shale in the upper part of the Argentine limestone of Iowa. Unfortunately, the holotype specimen of neither is entirely preserved or well oriented, and none of the paratypes of either, except for sagittal sec-

tions, is what could be called an excellent specimen. Both holotypes and paratypes have been restudied and are illustrated in this report. It is my conclusion that these two species are synonymous. It is somewhat unfortunate that the holotype specimen of *K.* (*K.*) *tenuis* is the poorer, but that name has priority.

The above description of *Kansanella* (*Kansanella*) *tenuis* is based on abundant specimens from the Iola limestone of Kansas; the holotype, paratype, and topotype specimens of *T. caccus* from the Argentine limestone of Iowa; and the holotype and paratype and numerous topotype specimens from the Wyandotte limestone of Miami County, Kansas.

Kansanella (*Kansanella*) *tenuis* resembles in general septal fluting and elongation and irregular shape of shell *K.* (*K.*) *neglecta* (Newell) and *K.* (*K.*) *plicatula* (Merchant & Keroher). These latter two species are somewhat more highly elongate than *K.* (*K.*) *tenuis*, are more nearly cylindrical in shape, and seeming all have more intensely fluted septa. They both have larger chomata and more distinct and heavier axial fillings.

Occurrence.—*Kansanella* (*Kansanella*) *tenuis* was originally described from the Island Creek (?) shale member of the Wyandotte limestone of Miami County, Kansas (K-254). It is abundant in the Iola limestone of Kansas (K-182), the Argentine limestone member of the Wyandotte of Iowa (I-60), and questionably in the Dewey limestone of Iowa (I-54).

KANSANELLA (KANSANELLA) OSAGENSIS (Newell)
Pl. 25, fig. 10–18

Triticites osagensis NEWELL, 1934, Jour. Paleont., vol. 8, p. 423, 424, pl. 52, fig. 4a–4f, pl. 53, fig. 4.

The shell of *Kansanella* (*Kansanella*) *osagensis* is one of the most highly elongate and slender of the American Pennsylvanian fusulinids. It has an irregular to broadly curving axis of coiling, bluntly pointed polar ends, and subparallel to irregular lateral slopes. Mature shells of six and a half to seven and a half volutions are 7.8 to 8.9 mm. long and 1.3 to 1.7 mm. wide, giving form ratios of 5.0 to 6.0. The first one to three volutions are short and ellipsoidal in shape, but beyond the third volution the axes of coiling rapidly elongate. Averages of the form ratios of the first to the seventh volution of five topotype specimens are 1.7, 2.4, 2.9, 3.4, 4.7, 5.4, and 5.4, respectively. A form ratio of 6.0 is attained in the sixth volution of some specimens.

The proloculus is spherical to slightly irregular in shape and has an outside diameter of 80 to 122 microns, averaging 96 microns for six specimens. The shell expands slowly for the first three to four volutions, and the outer volutions are relatively inflated. Averages of the heights of the chambers above the tunnel in the first to the seventh volution of eight specimens are 34, 42, 56, 82, 124, 186, and 240 microns, respectively.

The spirotheca is of moderate thickness. As was pointed out by Newell, the spirotheca increases in thickness sharply between the fourth and sixth volutions. Averages of the thicknesses of the spirotheca in the third to the seventh volution of eight topotype specimens are 18, 24, 36, 50, and 64 microns, respectively. The proloculus wall is considerably thicker than the spirotheca of the first two volutions. It is about 13 microns thick. The keriotheca has moderately coarse alveoli in the outer volutions and contains a thin upper keriotheca and relatively thick lower keriotheca. The two parts of the keriotheca are not very distinct in inner volutions. In contrast to most fusulinids, the spirotheca is thinnest in the tunnel area and thickens slightly poleward and is thickest in the polar ends just toward the middle of the shell.

The septa are closely spaced and are of moderate thickness. They are fluted somewhat irregularly throughout the length of the shell and completely to the tops of the chambers, and closed chamberlets are present even above the tunnel. Averages of the septal counts of the first to the seventh volution of three specimens are 12, 16, 18, 21, 24, 25, and 30, respectively.

The tunnel is narrow in the inner volution, and its path is about straight throughout the shell. Averages of the tunnel angles in the third to the seventh volution of five specimens are 26, 40, 49, 54, and 62 degrees, respectively. The chomata are very broad in the first three to four volutions and have steep tunnel sides and low poleward slopes. In outer volutions the chomata are more

Measurements of *Kansanella* (*Kansanella*) *osagensis* (Newell), in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							
					1	2	3	4	5	6	7	8
1	8.47	1.54	5.5	.101	.029	.040	.056	.073	.103	.161	—	—
2	8.38	1.58	5.3	.079	.036	.045	.052	.091	.150	.227	—	—
3	7.58	1.52	5.0	.113	.036	.050	.054	.093	.145	.181	—	—
4	8.87	1.49	6.0	.122	.035	.046	.063	.092	.134	.171	—	—
5	7.80	1.33	5.8	.080	.036	.044	.056	.080	.118	.188	—	—
6	—	1.63	—	—	.033	.039	.049	.070	.096	.152	.200	.249
7	—	1.68	—	.083	.034	.041	.058	.080	.118	.216	—	—
8	—	1.71	—	—	.035	.034	.062	.079	.124	.190	—	—

Specimen	Form ratio of volutions							Thickness of spirotheca							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
1	1.7	2.8	3.5	3.0	4.6	4.5	5.5	.012	.014	.019	.019	.029	.035	—	—
2	1.6	2.0	2.6	4.1	4.6	6.0	5.3	.012	.013	.013	.023	.041	.049	—	—
3	1.6	2.1	2.5	3.4	4.2	5.4	5.0	.012	—	.018	.026	.038	.055	.067	—
4	1.7	2.5	3.0	3.5	5.7	6.0	—	.011	.016	.018	.029	.033	.045	.060	–
5	1.8	2.8	2.9	3.2	4.2	4.9	5.8	.011	.015	.019	.023	.039	.056	.068	—
6	—	—	—	—	—	—	—	.010	.015	.018	.022	.029	.047	.054	.055
7	—	—	—	—	—	—	—	.012	.013	.021	.024	.040	.047	.057	—
8	—	—	—	—	—	—	—	.012	—	.019	.027	.037	.066	.078	—

Specimen	Septal count							Tunnel angle (degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	—	—	—	—	—	—	12	14	22	32	52	51	—
2	—	—	—	—	—	—	—	10	13	26	42	43	48	—
3	—	—	—	—	—	—	—	11	16	21	41	58	—	—
4	—	—	—	—	—	—	—	12	25	38	47	44	56	—
5	—	—	—	—	—	—	—	15	26	23	37	49	60	—
6	12	15	16	20	24	23	29	—	—	—	—	—	—	—
7	10	17	20	23	24	29	32	—	—	—	—	—	—	—
8	13	15	19	21	23	24	29	—	—	—	—	—	—	—

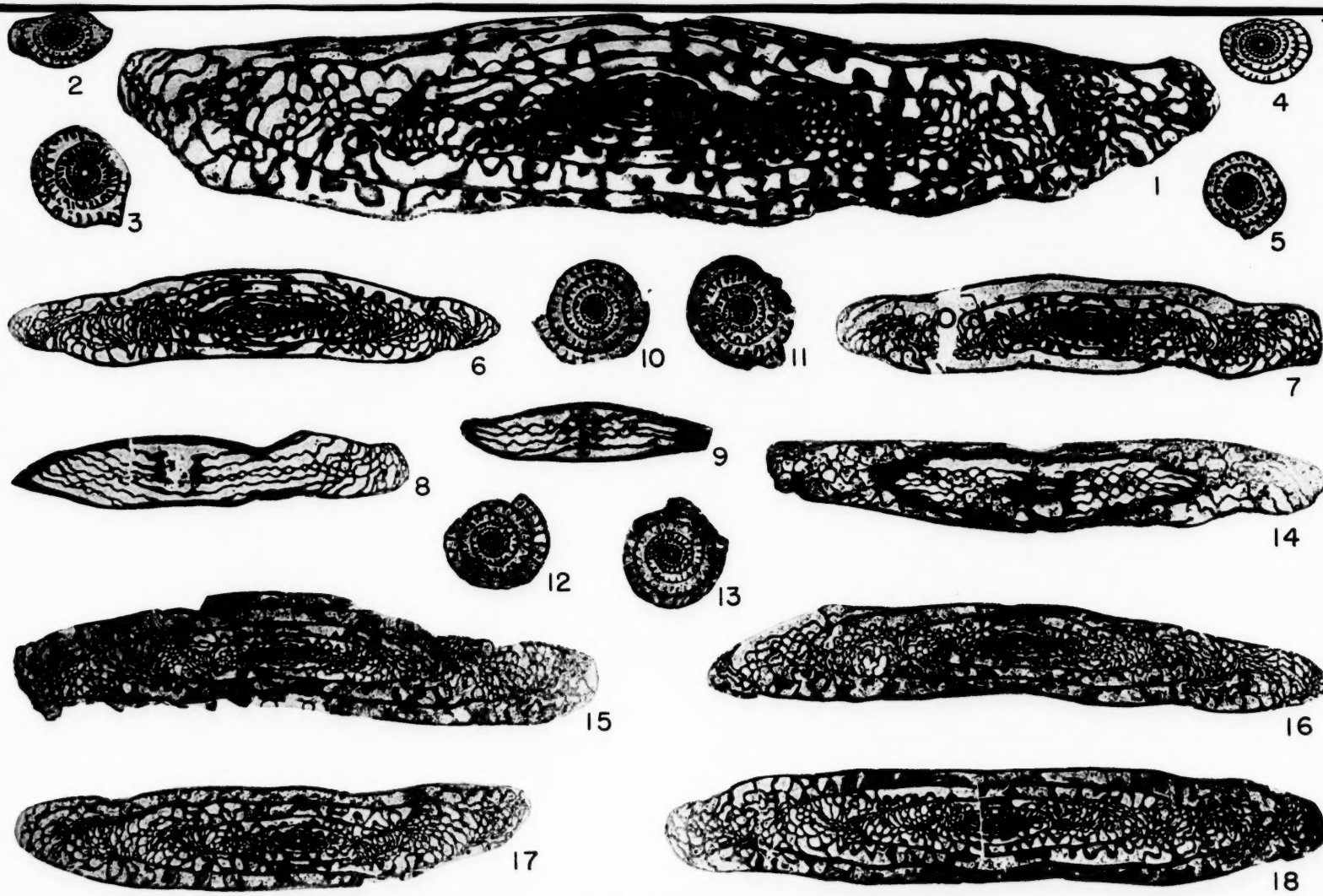
Explanation of Plate 25

All illustrations on this plate are unretouched photographs, and all are magnified ×10 except *1*, which is ×20.

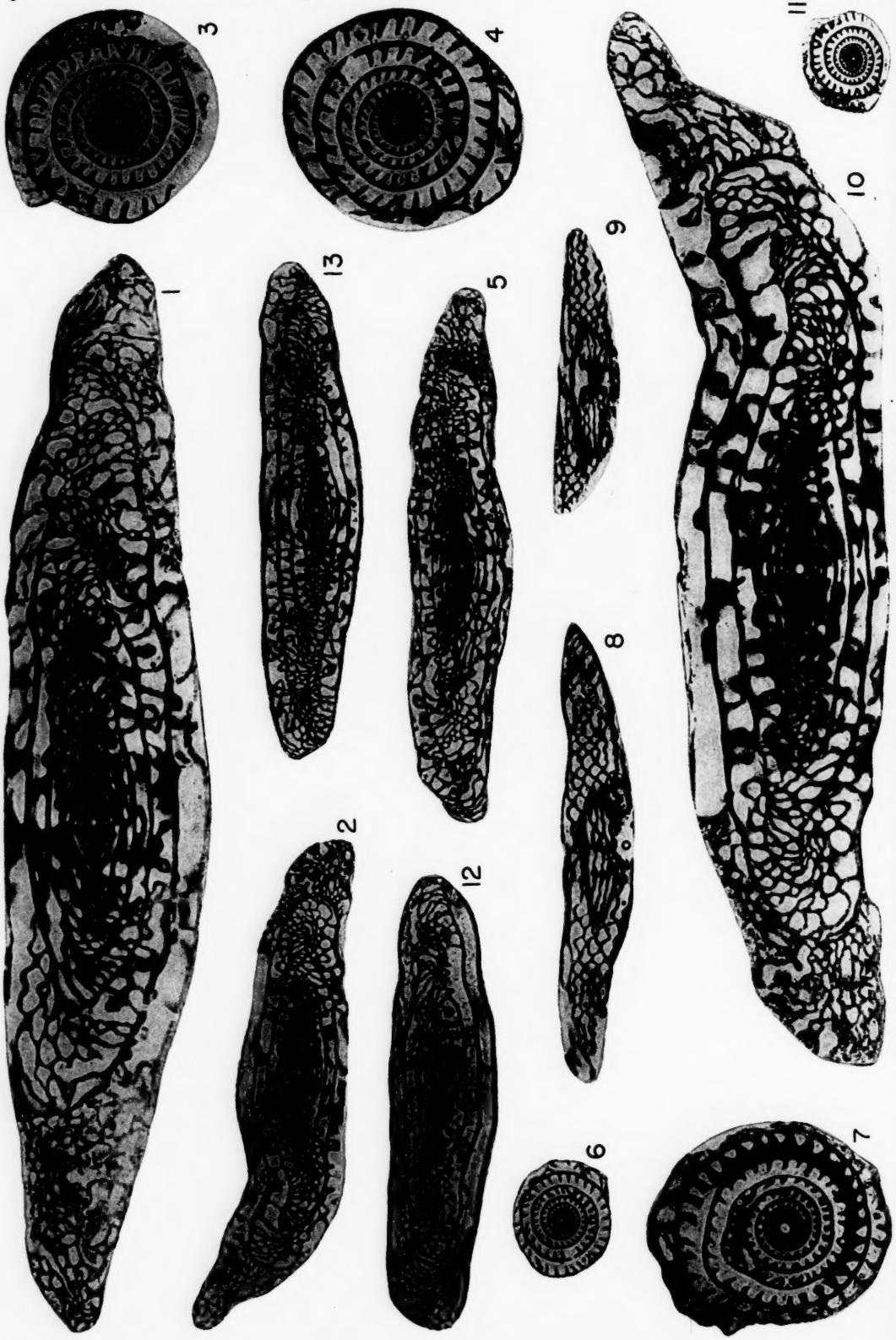
Fig. *1*—*Kansanella* (*Kansanella*) *joensis* Thompson, n. sp. Axial section of the holotype from the Iatan limestone (M-37). Specimen 2 of measurements.

2–9—*Kansanella* (*Kansanella*) *neglecta* (Newell). *2–5*, Sagittal sections; *6,7*, axial sections; and *8,9*, tangential sections showing the nature of fluting. *4,5,6*, and *7* are of specimens 7, 6, 2, and 4 of measurements. All from the Captain Creek limestone member of the Stanton limestone (K-214).

10–18—*Kansanella* (*Kansanella*) *osagensis* (Newell). *10–13*, Sagittal sections of topotypes; *14*, tangential section of a paratype showing nature of fluting; *15–17*, axial sections of topotypes; and *18*, axial section of the holotype. *10,11,12,16,17*, and *18* are of specimens 8, 7, 6, 4, 2, and 9 of measurements (O-4).



M. L. Thompson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nearly symmetrical. However, the chomata spread onto the septa completely to the polar ends of the inner four to five volutions and about half way to the poles of outer volutions. Light axial fillings occur throughout most inner volutions.

Remarks.—*Kansanella* (*Kansanella*) *osagensis* can be distinguished from most somewhat similar species by its more elongate and slender shell. It is perhaps most closely similar to *K.* (*K.*) *neglecta* from the Shawnee group. It can be distinguished from *K.* (*K.*) *neglecta* by its more loosely coiled shell, larger form ratio, larger tunnel angle, less massive chomata, more intensely fluted septa, and perhaps more uniform shell.

Occurrence.—*Kansanella* (*Kansanella*) *osagensis* is abundant in a limestone exposed in Osage County, Oklahoma (0–4) about two miles north of Avant and possibly in a calcareous sandstone four or five miles north of Bartlesville, Oklahoma. This general horizon is about 60 feet above the Avant limestone, the latter of which is considered to be equivalent in part at least to the Iola limestone of Kansas.

KANSANELLA (KANSANELLA) NEGLECTA (Newell)

Pl. 25, fig. 2–9; Pl. 26, fig. 12,13

Triticites neglectus NEWELL, 1934, Jour. Paleont., vol. 8, p. 422,423, pl. 52, fig. 2a,2b, pl. 53, fig. 1a,1b; BURMA, 1942, Jour. Paleont., vol. 16, p. 748, p. 118, fig. 3,6; (?) THOMPSON, VERVILLE, & BISSELL, 1950, Jour. Paleont., vol. 24, p. 454,455, pl. 59, fig. 7–12.

The shell of *Kansanella* (*Kansanella*) *neglecta* is irregularly elongate subcylindrical in shape; with arcuate to crooked axis of coiling, acute to blunt polar ends, and irregularly parallel lateral surfaces. Larger shells of six to seven volutions are 7.0 to 7.6 mm. long and 1.2 to 1.7 mm. wide, giving form ratios of 4.5 to 5.5. The first one to three volutions have acutely pointed polar ends and convex lateral surfaces, but the outer volutions have irregularly convex lateral surfaces which become more highly irregular with growth of the individual. Averages of the form ratios of the first to the seventh volution of four topotype specimens are 1.5, 1.9, 2.6, 3.0, 4.1, 4.8, and 5.2, respectively.

The proloculus is small and has an outside diameter of 90 to 131 microns, averaging 110 microns for five topotype specimens. The shell expands rather uniformly to the third or fourth volution and rapidly during the following volution. Averages of the heights of the chambers near the middle of the first to the seventh volution are 34, 41, 58, 80, 132, 170, and 203 microns, respectively.

The spirotheca is of near the same thickness throughout the length of the shell, except that it thins rapidly in the extreme polar ends. The proloculus wall is moderately thick but seems structureless. However, the spirotheca of the first two volutions is too thin to measure accurately. Averages of the thickness of the spirotheca near the center of the third to the seventh volution of seven topotypes are 15, 20, 30, 47, and 50 microns, respectively. Only the outer volutions show a distinctly keriothecal spirotheca.

The septa are closely spaced throughout the shell. Averages of the septal counts of the first to the seventh volution of three topotypes are 12, 17, 20, 23, 24, 27, and 31, respectively. The septa are fluted to some degree to the tops of the chambers throughout the length of the shell, so as to form

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EXPLANATION OF PLATE 26

All illustrations on this plate are unretouched photographs.

FIG. *1–11*—*Kansanella* (*Kansanella*) *joensis* Thompson, n. sp. *1,2,10*, Axial sections of paratypes; *5*, axial section of the holotype; *3,4,6,7,11*, sagittal sections of paratypes; and *8,9*, tangential sections of paratypes showing fluting. *1,3*(=*11*),*4*(=*6*),*5*, and *7* are of specimens 1, 6, 5, 2, and 4 of measurements. *1,3,4,7*, and *10* are magnified ×20, and all others are ×10. From the Iatan limestone (M-37).

12–13—*Kansanella* (*Kansanella*) *neglecta* (Newell). Axial sections of topotype (K-214), ×10. *12* is specimen 3 and *13* is specimen 1 of measurements.

closed chamberlets above the tunnel. Septal pores are abundant throughout the shell but seem more closely spaced in the polar areas.

The tunnel is narrow in the inner volution and becomes wide in outer volutions. The tunnel path is straight, and averages of the tunnel angles in the third to the sixth volution of four specimens are 29, 36, 47, and 52 degrees, respectively. The chomata are best developed in the inner three to four volutions where they have steep tunnel sides and very low poleward slopes that extend to the polar zones to join with light axial fillings. In outer volutions they are more nearly symmetrical and are considerably more narrow. Axial fillings are heavy in inner volutions where they almost fill the chambers. They are light and seem discontinuous in outer volutions.

Remarks.—*Kansanella* (*Kansanella*) *neglecta* resembles *K.* (*K.*) *osagensis* and *K.* (*K.*) *plicatula* more closely than any other species. It can be distinguished from *K.* (*K.*) *osagensis* with difficulty and may possibly be conspecific with that form. Many of the measurable features of both are of near the same value. However, *K.* (*K.*) *neglecta* seems to be somewhat smaller for specimens of equal volutions, and mature shells have smaller form ratios.

Kansanella (*Kansanella*) *plicatula* resembles *K.* (*K.*) *neglecta* somewhat closely and can be distinguished from this form most easily by its larger shell, more loosely coiled shell, larger form ratios for corre

Measurements of *Kansanella* (*Kansanella*) *neglecta* (Newell) (K-214), in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						
					1	2	3	4	5	6	7
1	7.56	1.55	4.9	.131	.037	.038	.064	.069	.115	.175	.207
2	7.43	1.36	5.5	.116	.034	.035	.048	.069	.112	.134	.209
3	7.63	1.70	4.5	—	.032	.045	.060	.111	.187	.220	.250
4	7.05	1.46	4.8	.090	.030	.037	.057	.081	.132	.177	.250
5	—	1.20	—	.104	.032	.037	.052	.066	.123	.170	—
6	—	1.24	—	—	—	.056	.061	.089	.144	.151	—
7	—	1.44	—	.108	.037	.042	.066	.077	.115	.164	.202

Specimen	Form ratio of volutions							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	1.9	2.1	2.7	3.6	3.9	4.8	4.9	—	.011	.014	.017	.023	.039	.055
2	1.5	1.7	2.5	2.7	4.2	4.8	5.5	.012	.012	.014	.016	.023	.037	.054
3	1.4	1.8	2.4	2.9	4.0	4.8	—	.011	.013	.015	.027	.047	.062	.066
4	1.3	2.1	2.9	2.8	4.4	5.0	—	.010	.013	.015	.019	.026	.054	.062
5	—	—	—	—	—	—	—	.012	.013	.015	.020	.033	.043	—
6	—	—	—	—	—	—	—	—	.014	.015	.019	.031	.046	—
7	—	—	—	—	—	—	—	.013	.015	.017	.022	.029	.051	.061

Specimen	Septal count							Tunnel angles (degrees)					
	1	2	3	4	5	6	7	1	2	3	4	5	6
1	—	—	—	—	—	—	—	15	17	27	32	37	48
2	—	—	—	—	—	—	—	20	23	31	32	50	56
3	—	—	—	—	—	—	—	16	20	31	42	43	—
4	—	—	—	—	—	—	—	16	19	25	39	59	—
5	13	18	20	24	24	28	—	—	—	—	—	—	—
6	11	16	19	24	23	26	—	—	—	—	—	—	—
7	12	18	20	22	25	27	31	—	—	—	—	—	—

sponding volutions, and perhaps more irregularly fluted septa.

Occurrence.—*Kansanella* (*Kansanella*) *neglecta* is abundant in the Captain Creek limestone member of the Stanton limestone (K-214). The above description is based on topotype specimens from Miami County, Kansas (K-214). Specimens here referred with question to this species were described by Thompson, Verville, & Bissell from the Oquirrh formation of Utah. It now seems unlikely that the Utah specimens are closely related to this form.

KANSANELLA (KANSANELLA) PLICATULA (Merchant & Keroher)
Pl. 24, fig. 1–13

Triticites plicatulus MERCHANT & KEROHER, 1939, Jour. Paleont., vol. 13, p. 609–611, pl. 60, fig. 13–15. BURMA, 1942, Jour. Paleont., vol. 16, p. 747–748. (?) THOMPSON, VERVILLE, & BISSELL, 1950, Jour. Paleont., vol. 24, p. 453–454, pl. 60, fig. 16, pl. 61, fig. 11–16.

The shell of *Kansanella* (*Kansanella*) *plicatula* is large and elongate subcylindrical in shape; with irregular to arcuate axis of coiling, broadly rounded to bluntly pointed polar ends, and irregular lateral slopes. Larger shells of six and a half to nine volutions are 9.2 to 10.2 mm. long and 1.8 to 2.6 mm. wide, giving a form ratio of 3.8 to 5.1. The first three or four volutions are inflated fusiform in shape, with pointed polar ends and convex lateral slopes, but the outer volutions have about parallel lateral slopes and more blunt polar ends. Averages of the form ratios of the first to the seventh volution of the holotype and four topotype specimens are 1.3, 2.2, 2.3, 2.5, 3.8, 4.2, and 4.3, respectively.

The proloculus is small, and its outside diameter measures 88 to 117 microns, averaging 101 microns for eleven specimens. The first two to three volutions are tightly coiled, but the outer volutions gradually become more loosely coiled. Averages of the height of the chambers near the tunnel of the first to the ninth volution of eleven specimens, including the holotype, are 36, 50, 72, 105, 161, 208, 255, 266, and 250 microns, respectively. As these figures show, the last three volutions are near the same height with the last volution of most large specimens decreasing slightly. The chambers are of about the same height in the central half of the shell but they increase in height sharply in the extreme polar areas.

The spirotheca is thin in comparison to the large size of the shell. It is distinctly alveolar but the alveoli of the keriotheca show best in outer volutions. Averages of the thicknesses of the spirotheca in the third to the ninth volution of eleven specimens are 19, 24, 34, 52, 64, 70, and 73 microns, respectively. The proloculus wall measures about 12 microns.

The septa are closely spaced in inner volutions but become widely spaced in outer volutions of mature specimens. They are moderately thick and are composed of a distinct pycnotheca as in other schwagerinids. Averages of the septal counts of the first to the eighth volution of six specimens are 12, 18, 20, 24, 24, 28, 29, and 30, respectively. The septa are fluted throughout the length of the shell so as to form closed chamberlets to above the tunnel, and they are broadly and regularly fluted to the tops of the chambers. However, the fluting does not seem of uniform intensity at a given height along the septa. Also, the fluting is highly irregular along the septa with variable degrees of intensity in all directions. The heights of the folds become greater, however, toward the polar ends and reach the tops of the chambers in the polar region.

The tunnel is relatively narrow and its path is about straight. Averages of the tunnel angle in the third to the seventh volution of five specimens are 25, 34, 48, 54, and 49 degrees, respectively. The chomata are about half to two-thirds as high as the chambers and are wide in inner volutions and narrow in outer volutions. Their low lateral slopes extend to the poles in the third to fourth volutions but the lateral slopes in the outer few volutions are steep. Axial fillings seem confined to the inner volutions.

Remarks.—*Kansanella* (*Kansanella*) *plicatula* is one of the largest of the Missourian fusulinids in the midcontinent region. It can be distinguished from most other Missourian fusulinids by its long irregular and large shell, rather intensely fluted septa, and relatively thin spirotheca. It resembles most closely *K.* (*K.*) *neglecta* (Newell) and *K.* (*K.*) *osagensis* (Newell). From the latter it can be distinguished by its larger shell, thicker

Measurements of *Kansanella* (*Kansanella*) *plicatula* (Merchant & Keroher), in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions								
					1	2	3	4	5	6	7	8	9
1	9.58	2.04	4.7	.102	.033	.040	.053	.084	.111	.217	.297	.289	—
2	10.24	2.18	4.7	.092	.037	.046	.088	.122	.183	.263	.267	—	—
3	9.13	1.99	4.5	.117	.040	.059	.061	.099	.176	.201	.244	—	—
4	9.21	1.81	5.1	—	.039	.064	.111	.131	.210	.223	.248	—	—
5	9.29	2.47	3.8	.115	.036	.051	.077	.121	.150	.235	.324	.256	—
6	—	2.56	—	.111	.038	.054	.066	.089	.154	.159	.226	.281	.264
7	—	2.05	—	.088	.032	.051	.074	.136	.209	.217	.249	.311	—
8	—	2.12	—	.090	.033	.044	.055	.068	.106	.151	.213	.241	.236
9	—	1.86	—	.117	.032	.041	.064	.103	.159	.219	.230	—	—
10	—	2.15	—	.088	.037	.053	.079	.124	.191	.249	.256	—	—
11				.088	.034	.041	.069	.079	.117	.159	.248	.218	—

Specimen	Form ratio of volutions								Thickness of spirotheca								
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9
1	1.2	2.1	2.2	2.8	3.5	4.1	4.3	—	.010	.010	.014	.017	.021	.042	.067	.073	—
2	1.2	2.4	2.2	2.5	4.3	4.5	4.5	—	.011	—	.020	.030	.044	.070	.088	—	—
3	1.1	2.0	2.2	2.5	3.8	4.2	4.4	—	—	—	.016	.021	.031	.052	.059	—	—
4	1.3	2.1	2.4	3.5	4.2	4.7	—	—	—	.015	.024	.031	.046	.056	.061	—	—
5	1.7	2.4	2.6	2.9	3.1	3.5	3.9	3.8	.010	.011	.016	.026	.033	.059	.070	.066	—
6	—	—	—	—	—	—	—	—	—	—	.020	.022	.034	.052	.054	.064	.068
7	—	—	—	—	—	—	—	—	—	.015	.022	.032	.040	.056	.058	.080	—
8	—	—	—	—	—	—	—	—	—	—	.016	.016	.028	.030	.068	.066	.079
9	—	—	—	—	—	—	—	—	.012	.016	.020	.022	.032	.051	.060	—	—
10	—	—	—	—	—	—	—	—	.012	.017	.024	.029	.034	.051	.057	—	—
11	—	—	—	—	—	—	—	—	.011	.017	.022	.027	.030	.050	.060	.068	—

Specimen	Septal count									Tunnel angle (degrees)							
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8
1	—	—	—	—	—	—	—	—	—	—	—	12	24	31	34	58	—
2	—	—	—	—	—	—	—	—	—	—	—	21	36	58	74	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—	—	46	66	—	—
4	—	—	—	—	—	—	—	—	—	—	—	33	37	58	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	45	37	46	41	40	—
6	—	25	26	28	29	34	32	36	35	—	—	—	—	—	—	—	—
7	11	20	19	24	26	29	34	—	—	—	—	—	—	—	—	—	—
8	13	—	17	21	20	24	27	30	—	—	—	—	—	—	—	—	—
9	13	17	22	24	24	26	24	—	—	—	—	—	—	—	—	—	—
10	12	15	22	20	21	25	29	—	—	—	—	—	—	—	—	—	—
11	10	15	15	26	26	28	27	25	—	—	—	—	—	—	—	—	—

shell, and more widely spaced septa. From the former it can be distinguished by its larger shell in all features, more inflated outer volution, and more blunt polar ends near maturity.

After a detailed study of the holotype and paratype specimens of *Kansanella* (*Kansanella*) *plicatula* and numerous well-preserved topotype specimens it is considered that the species described and illustrated by Thompson, Verville, & Bissell as *Triticites plicatulus?* from the Oquirrh formation of Utah can be distinguished from that species by its less intensely fluted septa and larger tunnel angles for corresponding volutions. However, it is entirely possible

that these differences are due in part to environmental conditions and the two may be of the same species. Until the geographic variation of species are determined and the effect of environments are better understood, they will remain referred to with question as the same species.

Occurrence.—*Kansanella* (*Kansanella*) *plicatula* is abundant in the Spring Hill limestone member of the Plattsburg limestone (K-250). Specimens referred with question to this species are abundant in the Oquirrh formation of Utah.

Genus TRITICITES Girty
TRITICITES OHIOENSIS Thompson
Pl. 27, fig. 1–8

Triticites irregularis DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, 2nd ser., p. 108–111, pl. 8, fig. 7–10 (1927). (? part) WHITE, 1932, Univ. Texas Bull., No. 3211, p. 51–52, pl. 4, fig. 7–9. NEWELL, 1934, Jour. Paleont., vol. 8, p. 423, pl. 52, fig. 1. (?) MERCHANT & KEROHER, 1939, Jour. Paleont., vol. 13, p. 600–603, text fig. 2–1, pl. 69, fig. 4. BURMA, 1942, Jour. Paleont., vol. 16, p. 743. (*Not* Staff, 1912)

Triticites ohioensis THOMPSON, 1936, Jour. Paleont., vol. 10, p. 680–682, pl. 91, fig. 1–3. DUNBAR & HENBEST, 1942, Ill. Geol. Survey, Bull. 67, p. 130–132, pl. 19, fig. 1–22, pl. 20, fig. 20–24. THOMPSON, 1948, Kansas Univ. Paleont. Contr., art. 1, pl. 8, fig. 5. (*Not* Thompson, Verville & Bissell, 1950)

The shell of *Triticites ohioensis* is moderately large in size and highly elongate subcylindrical in shape; with irregular, broadly curving, to straight axis of coiling, pointed to blunt polar ends, and parallel to irregular or slightly sloping lateral slopes. Mature shells of six to seven and a half volutions are 6.8 to 9.0 mm. long and 1.5 to 1.8 mm. wide, giving form ratios of 4.0 to 5.0. The average form ratio of eight specimens is about 4.6. The first two to three volutions are ellipsoidal in shape with convex lateral surfaces and narrowly rounded polar ends, and the following two to three volutions have subparallel irregular lateral slopes and more blunt polar ends. Averages of the form ratios of the first to the seventh volution of four specimens are 1.3, 2.3, 2.7, 3.5, 3.7, 4.4, and 4.6, respectively.

The proloculus is minute and has an outside diameter of 66 to 86 microns, averaging 79 microns for six specimens. The shell expands rather slowly and uniformly throughout growth. The chambers are about 34, 46, 81, 121, 178, 207, and 211 microns high above the tunnel in the first to the seventh volution, respectively, in seven specimens. The chambers are lowest above the tunnel, and they increase in height slowly poleward for about half the distance to the polar ends and increase in height sharply in the polar end of the shell. Since the lateral slopes are irregular, the heights of the chambers are variable in any given specimen in the end areas.

The spirotheca is thin but has a structure typical of the genus throughout the shell. It is of nearly the same thickness throughout the central two-thirds of the length of the shell. The keriotheca of the inner three to four volutions is thin and does not show distinct alveoli in all specimens. It is evident, however, that the keriotheca is alveolar as in higher forms of the genus with thicker keriotheca. Averages of the thickness of the spirotheca above the tunnel in the first to the seventh volution of seven specimens are 8, 12, 19, 28, 39, 51, and 46 microns, respectively. The proloculus wall measures about 9 microns.

The septa are closely spaced. They are irregularly and highly fluted in the polar quarters of the shell but are only slightly irregular in the central part of the shell. Their attitude is almost perfectly normal to the tangent in the area of the tunnel. Averages of the septal counts in the first to the sixth volution of three specimens are 10, 14, 17, 20, 24, and 26, respectively. Septal pores are abundant.

The tunnel is very broad, and its path is slightly irregular. The tunnel width increases rapidly from the third volution to maturity. Averages of the tunnel angles in the third to the sixth volution are 26, 33, 42, and 47 degrees, respectively. The chomata are very broad and highly asymmetrical in the inner three to four volutions. In fact, they extend to the polar areas in the first two volutions. They become narrow and more nearly symmetrical in outer volutions.

Remarks.—The above description of *Triticites ohioensis* is based entirely on specimens from the lower part of the Winterset limestone, Iowa (I-50). However, specimens are also illustrated from 8 feet higher in the

Winterset (I-53). The large, elongate, and narrow shell and the slight fluting of the septa in the central part of the shell of *Triticites ohioensis* distinguish it from most other Missourian species of *Triticites*.

Staff (1912) proposed the name *Fusulina centralis irregularis* for various collections of fusulinids from North America. It is evident that he referred a large variety of fusulinids to the subspecies. However, Thompson (1936) redefined the form as *Triticites irregularis* (Staff) to the extent that he selected as the holotype the specimen from Kansas illustrated by Staff as figure 10 on his plate 13. Unfortunately, Staff did not give the locality or stratigraphic position of this specimen and he did not indicate its magnification. Since so little information is available concerning the holotype specimen of *T. irregularis* it may be impossible to determine its features until Staff's specimen is restudied.

Thompson (1936) took the stand that since the holotype of *Triticites irregularis* is so poorly understood we should define the species as including the species so abundant in the Winterset limestone of Iowa. However, the holotype specimen has a shape that is different from the Winterset specimens. Furthermore, there are several species in the Kansas Missourian section which seem more closely similar to the holotype than does the form from Iowa. Until a restudy of the holotype is made, *T. irregularis* must remain an unidentifiable species.

Several differences were pointed out by Thompson between the type specimens of *Triticites ohioensis* and the specimens so abundant in the Winterset limestone of Iowa. Further collections from the Winterset, however, have yielded a great abundance of specimens from the lower part of the Winterset, 8 feet below the specimen studied earlier, which seem almost identical to the holotype of *T. ohioensis*. Furthermore, numerous measurements of specimens from throughout the Winterset seem to demonstrate that only one species is present in this abundant fauna of long slender *Triticites*.

Triticites ohioensis is associated in the upper part of the Winterset (I-50) and the lower part of the Winterset (I-53) with scarce specimens of *Kansanella* (*Iowanella*) *winterensis* and in the middle part of the Winterset (I-44) with abundant specimens of the same species.

Occurrence.—*Triticites ohioensis* has been

Measurements of *Triticites ohioensis* Thompson, in mm. (I-50)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							Form ratio of volutions						
					1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	8.2	1.8	4.6	—	.031	.051	.076	.120	.180	.230	—	1.2	1.9	1.9	2.6	4.4	4.1	4.6
2	7.0	1.7	4.0	.079	.029	.049	.073	.117	.166	.234	—	1.5	2.2	2.6	3.5	4.3	4.7	4.0
3	7.6	1.6	4.7	.070	.026	.045	.068	.098	.201	.246	—	2.0	3.0	3.0	4.6	4.7	—	—
4	9.0	1.8	4.9	—	—	.057	.081	.131	.187	.200	—	1.3	1.9	2.7	4.2	4.4	5.1	4.7
5	—	1.5	—	.079	.033	.046	.088	.141	.218	.236	—	—	—	—	—	—	—	—
6	—	1.5	—	—	.027	.039	.061	.092	.161	.227	.234	—	—	—	—	—	—	—
7	—	1.7	—	—	—	.038	.057	.081	.089	—	—	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count							Tunnel angle (degrees)					
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6
1	.012	.019	.023	.035	.044	.051	—	—	—	—	—	—	—	—	—	—	21	27	39	44
2	.011	.018	.027	.034	.043	.056	—	—	—	—	—	—	—	—	—	—	20	30	36	49
3	—	.020	.022	.030	.051	.045	—	—	—	—	—	—	—	—	—	—	24	31	40	46
4	—	.021	.024	.035	.043	.057	—	—	—	—	—	—	—	—	—	—	33	36	42	47
5	.014	.023	.027	.034	.041	.052	—	12	15	16	20	24	27	—	—	—	—	—	—	—
6	—	—	.021	.033	.039	.068	.070	10	14	18	20	22	24	24	—	—	—	—	—	—
7	—	.010	.018	.023	.034	—	—	—	14	16	20	23	24	—	—	—	—	—	—	—

identified from the Cambridge and Brush Creek limestones of Ohio, the Livingston and Omega limestones of Illinois, from a limestone in western Kentucky, and is abundant in the Winterset limestone of Iowa (I-50, I-44, I-53). The species *T. irregularis* has been identified from numerous areas of central United States, including Kansas (Staff, 1912; Merchant & Keroher, 1939), central Texas (Dunbar & Condra, 1928; White, 1932), and Utah (Thompson, Verville & Bissell, 1950). Since *T. irregularis* has been defined most commonly in the past as including the Winterset species here described as *T. ohioensis*, it seems likely that some of these other occurrences may also refer to this species. Some of them, however, are not considered to represent this species.

TRITICITES COLLUS Burma
Pl. 27, fig. 9–15

Triticites collus BURMA, 1942, Jour. Paleont., vol. 16, p. 744, pl. 118, fig. 9–14.

Triticites collus was described by Burma from the Dewey limestone exposed southwest of Winterset, Iowa. It seems that he may have had a number of specimens on which the species was based, but he illustrated only one axial and one sagittal section. The axial section illustrated by his figure 9 on plate 118 is here designated as the holotype. This seems especially necessary since two species are present in the Dewey at this locality, and he may well have been studying some of both. Only the holotype axial section and the illustrated sagittal section are present among Burma's types at Wisconsin.

I have obtained numerous topotype specimens which are conspecific with the holotype and the measurements here given are taken from Burma's type specimens and from topotype specimens.

The shell of *Triticites collus* is elongate fusiform in shape; with curved or near straight axis of coiling, slightly convex to regular lateral slopes, and blunt to narrowly rounded polar ends. Larger shells of seven to eight volutions are 6.4 to 7.6 mm. long and 1.6 to 2.1 mm. wide, giving form ratios of 3.6 to 4.3. The first volution is short and inflated, but the shell rapidly becomes elongated as maturity is approached. Average form ratios of the first to the seventh volution of four specimens, including the holotype, are 1.2, 2.0, 2.4, 2.5, 2.7, 3.5, and 4.0, respectively.

The proloculus is small and has an outside diameter of 70 to 95 microns, averaging 82 microns for six specimens. The shell expands slowly but about uniformly. Averages of the heights of the chambers in the first to the eighth volution of six specimens are 29, 41, 60, 85, 90, 189, 219, and 210 microns, respectively.

The spirotheca is thin but is distinctly alveolar in all volutions. It is thickest above the tunnel but becomes thinner slowly toward the poles. The proloculus wall is only about 8 microns thick. Averages of the thicknesses of the spirotheca in the third to the eighth volution of six specimens are 14, 18, 27, 40, 63, and 45 microns, respectively.

The septa are thin and are numerous. Averages of the septal counts of the first to the seventh volution are about 12, 19, 22, 25, 28, 33, and 34, respectively. The septa are fluted completely to the tops of the chambers in the polar region, but they are fluted only in their lower half across the middle of the shell. Although the fluting extends across the shell it does not seem to be regular. Septal pores are abundant.

The tunnel is narrow in the inner three to four volutions but it becomes moderately wide in the outer two to three volutions. The chomata are very high and broad in the inner four or five volutions but they become narrow but high in outer volutions. In the inner volutions their tunnel sides are steep but their lateral sides are low and extend to the polar zones. Averages of the tunnel angles in the third to the seventh volution of five specimens are 23, 26, 36, 48, and 52 degrees, respectively.

Remarks.—Triticites collus can be distinguished from most other fusulinids in lower Missourian rocks by its large size, massive chomata, and more intensely fluted septa. This is especially true for distinguishing it from *T. nebraskensis*, *T. burgessae*, and *T. pygmaeus*. It can be distinguished from *T. ohioensis* by its shorter shell, more highly fluted septa, and more massive chomata.

Occurrence.—Triticites collus is abundant in the upper part of the Dewey limestone in Iowa (I-45, I-54, I-8). The holotypes came from the same locality.

Measurements of *Triticites collus* Burma, in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							
					1	2	3	4	5	6	7	8
1	6.4	1.6	3.6	.095	.034	.049	.059	.106	.152	.199	.188	—
2	—	2.1	—	.083	.029	.040	.089	.104	.122	.189	.223	.239
3	7.6	1.8	4.3	.070	.030	.035	.068	.070	.129	.214	—	—
4	6.6	1.8	4.1	.086	.027	.033	.056	.067	.107	.193	.224	—
5	6.4	1.6	4.1	.078	.032	.045	.035	.087	.111	.177	—	—
10	—	1.6	—	.080	.025	.041	.052	.076	.099	.167	.221	.181

Specimen	Form ratio of volutions							Thickness of spirotheca							
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8
1	1.5	2.3	2.5	2.7	3.0	3.5	4.1	—	.009	.012	.016	.033	.048	.049	—
2	—	—	—	—	—	—	—	.011	.013	.019	.022	.026	.034	.059	.048
3	1.9	2.0	2.5	3.0	3.4	4.1	4.3	.007	.009	.012	.016	.030	.049	.065	—
4	1.0	1.5	2.0	2.3	2.7	2.7	3.3	.008	.010	.016	.020	.023	.035	.054	—
5	1.4	2.0	2.6	2.9	2.8	3.5	4.2	.009	—	.011	.021	.027	.041	—	—
10	—	—	—	—	—	—	—	.008	.011	.012	.015	.025	.035	.039	.043

Specimen	Septal count							Tunnel angle (degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	—	—	—	—	—	—	—	—	17	23	36	47	—
2	10	16	20	23	29	33	33	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	29	35	42	55	—
4	—	—	—	—	—	—	—	—	—	22	31	42	52	—
5	—	—	—	—	—	—	—	—	—	17	24	37	49	52
6	—	—	—	—	—	—	—	—	—	31	18	24	37	—

Specimens 1 and 2 are original types and others are from Collection I-45.

TRITICITES BURGESSAE Burma
Pl. 28, fig. 1–6,7?

Triticites burgessae BURMA, 1942, Jour. Paleont., vol. 16, p. 744, pl. 118, fig. 2,13.

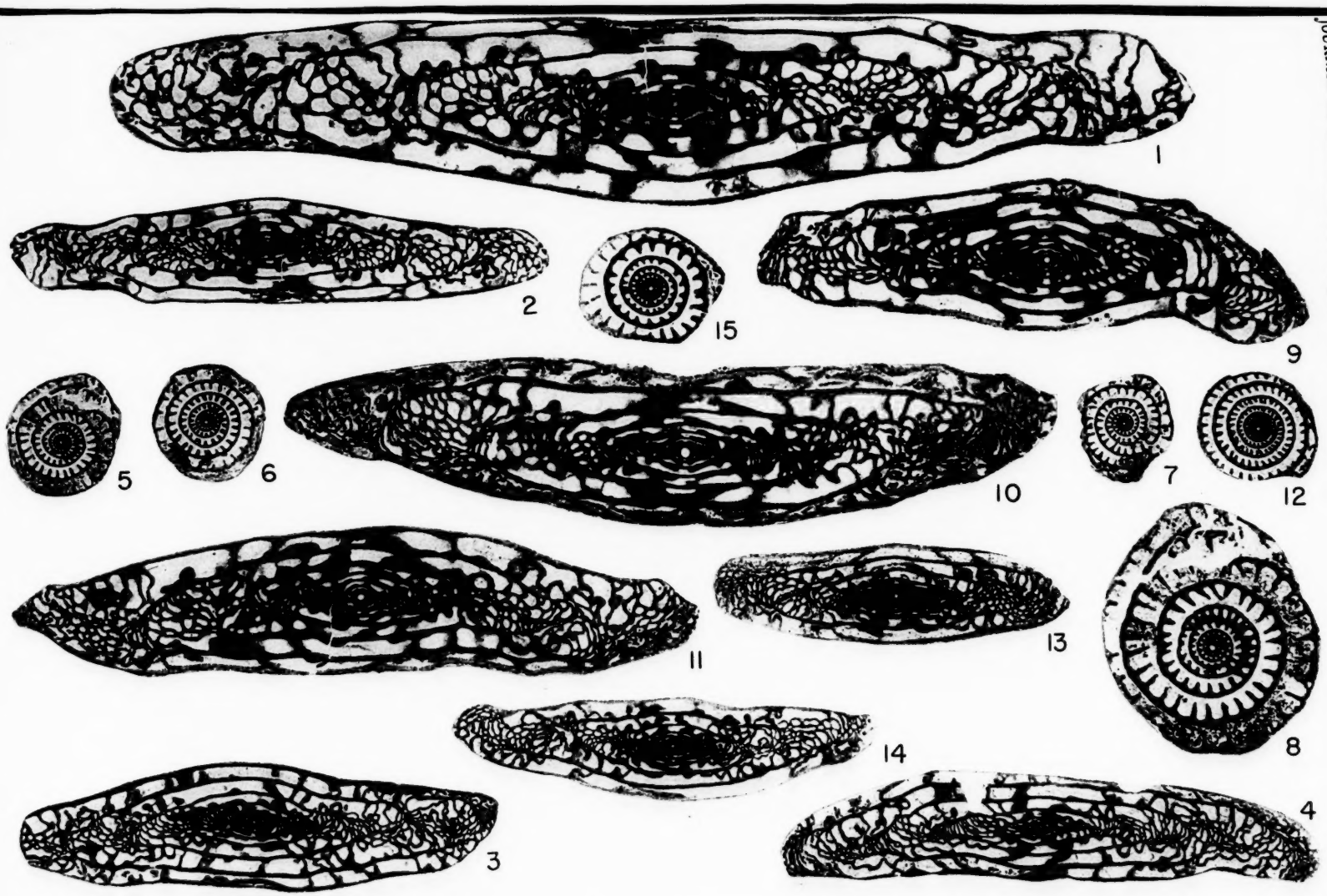
The shell of *Triticites burgessae* is minute in size and inflated fusiform in shape; with a straight axis of coiling, bluntly pointed polar ends, and convex but steep lateral slopes. Mature shells of five and a half to seven volutions are 2.8 to 3.5 mm. long and 1.1 to 1.5 mm. wide, giving form ratios of 2.2 to 2.6. In general, the form ratio increases to the fourth or fifth volution and decreases slightly from there to maturity. A typical topotype specimen of seven volu-

EXPLANATION OF PLATE 27

All illustrations on this plate are unretouched photographs. Figures *1,8–11*, and *15* are ×20, and all others are ×10.

FIG. *1–8—Triticites ohioensis* Thompson. *1–4*, Axial sections; and *5–8*, sagittal sections. *1(=2)* is of specimen 4 of measurements. *1–3* are from the upper shale of the Winterset limestone at Winterset, Iowa (I-50), and all others are from the lower shale of the Winterset (I-53).

9–15—Triticites collus Burma. *9–11,14*, Axial sections of topotypes; *12*, sagittal section of a paratype; *13*, axial section of the holotype; and *15*, sagittal section of a topotype. *9,10,11*, and *15* are from the lower Dewey limestone of Iowa (I-45) and *14* is from the upper Dewey limestone at the same locality (I-54). *9,10*, and *11* are of specimens 6, 3, and 5 of measurements.



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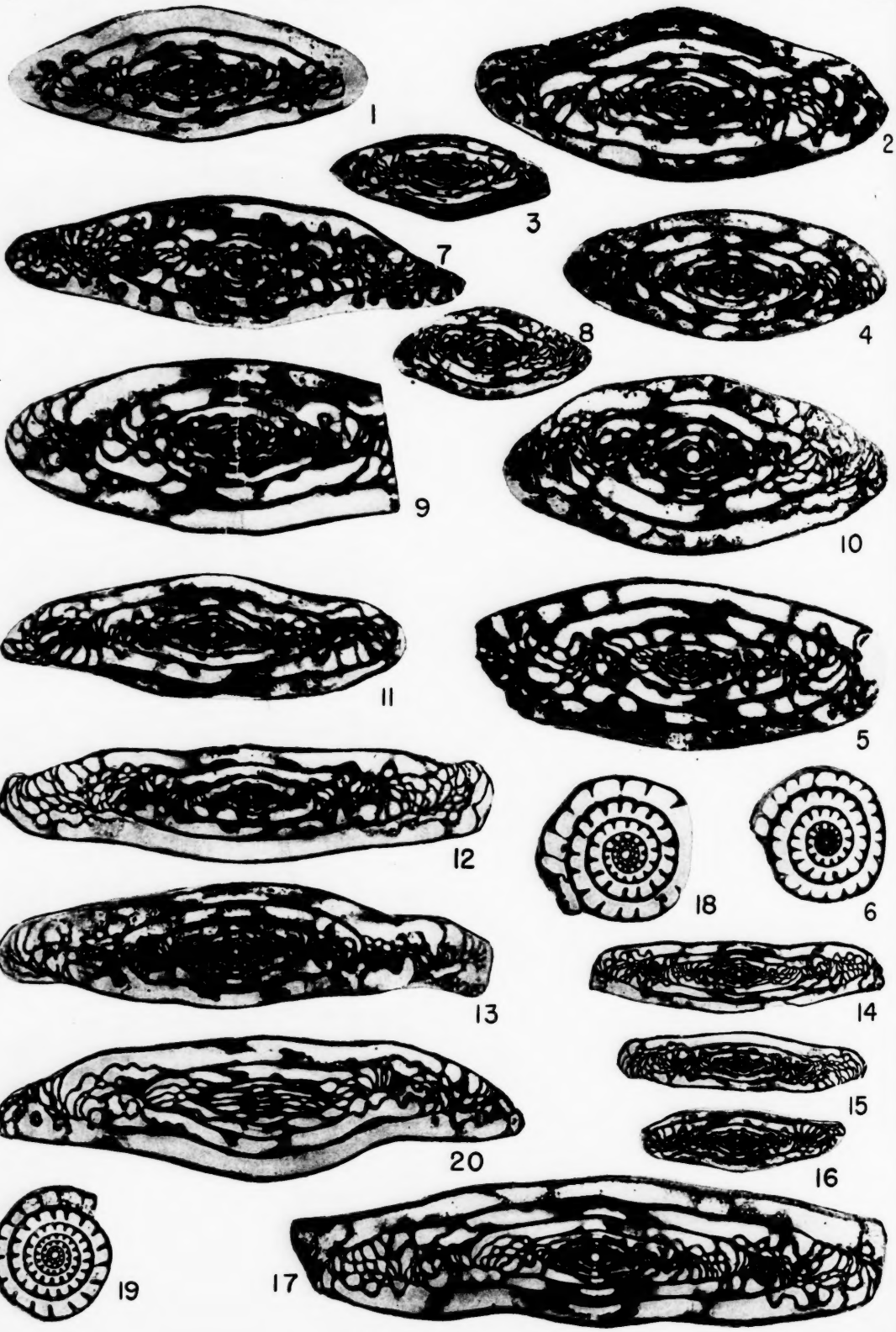

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Measurements of *Triticites burgessae* Burma, in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						
					1	2	3	4	5	6	7
1	2.8	1.3	2.2	.045	.023	.033	.052	.067	.099	.150	.153
2	3.5	1.5	2.4	.053	.032	.038	.060	.075	.115	.170	.189
3	3.4	1.5	2.3	.048	.022	.031	.044	.075	.131	.208	.193
5	—	1.2	—	—	.028	.032	.065	.125	.155	—	—
8	2.9	1.1	2.6	.076	.027	.045	.067	.117	.147	—	—
9	—	1.2	—	.069	.022	.043	.083	.121	.155	.165	—
10	—	1.2	—	.082	.031	.059	.082	.143	—	—	—
11	—	1.2	—	.054	.029	.033	.057	.089	.122	—	—

Specimen	Form ratio of volutions							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	1.0	1.3	1.6	2.2	2.0	2.1	2.2	—	.009	.013	.021	.031	.035	.040
2	1.5	1.6	2.0	2.5	2.5	2.3	2.4	.009	.010	.012	.016	.027	.055	—
3	1.1	1.8	2.1	2.5	2.5	2.7	2.3	.008	.011	.014	.017	.028	.040	.054
5	1.7	2.1	3.3	4.1	4.1	—	—	.007	.008	.018	.030	.041	—	—
8	1.4	2.3	2.8	2.7	2.7	—	—	.008	.012	.017	.027	.031	—	—
9	—	—	—	—	—	—	—	—	.012	.017	.025	.043	.056	—
10	—	—	—	—	—	—	—	.010	.013	.020	.033	—	—	—
11	—	—	—	—	—	—	—	.009	.011	.013	.028	.036	—	—

Specimen	Septal count				
	1	2	3	4	5
9	10	12	13	17	20
10	8	13	13	18	—
11	10	11	14	19	19

Specimen	Tunnel angle (degrees)					
	1	2	3	4	5	6
1	—	—	28	33	37	41
2	—	—	18	29	42	38
3	—	—	30	36	47	—
5	—	—	—	—	—	—
8	—	—	36	37	—	—
9	—	—	—	—	—	—
10	—	—	—	—	—	—

Specimens 1–3, 5, 10, 11 (I-59); 8, holotype, 9, paratype.

Explanation of Plate 28

All illustrations on this plate are unretouched photographs.

Fig. *1–6, 7?—Triticites burgessae* Burma. *1*, Axial section of the holotype, ×20; *2,4,5*, axial sections of topotypes, ×20; *3*, axial section same as *2*, ×10; *6*, sagittal section of a paratype, ×20; and *7*, axial section with fluted septa referred with question to this species, ×20. *1,2(=3),4,5*, and *6* are of specimens 8, 2, 1, 3, and 9 of measurements. All from shale in the Westerville limestone of the Cherryvale shale (I-59).

8–10—Triticites pygmaeus Dunbar & Condra. Axial sections of syntypes. *8(=10)* is specimen 5 and *9* is 4 of measurements. *8* is ×10 and *9* and *10* are ×20. All from Louisville, Nebraska (N-5).

11–20—Triticites nebraskensis Thompson. *11,13,16*, Axial sections of syntypes; *12,14,15,17*, axial sections; *18,19*, sagittal sections; and *20*, tangential section. *11–13* and *17–20* are ×20, and others are ×10. *11(=16),13,14(=17)*, and *19* are of specimens 1, 3, 4, and 8 of measurements. *12,15*, and *18* are from the Cherryvale shale of Iowa (I-6) and *14,17,19*, and *20* are from the same horizon and locality (I-47).

tions has a form ratio for the first to the seventh volution of 1.5, 1.6, 2.0, 2.5, 2.5, 2.3, and 2.4, respectively. Averages of the form ratios of the first to the seventh volution of five specimens, including the holotype, are 1.3, 1.8, 2.4, 2.8, 2.7, 2.4, and 2.3, respectively.

The proloculus is minute in size and has an outside diameter of only 46 to 86 microns, averaging only 61 microns for seven specimens. The shell is tightly coiled throughout. Average heights of the first to the seventh volution of eight specimens are 29, 39, 65, 101, 132, 173, and 178 microns, respectively.

The spirotheca is thin but has a structure typical of the genus. Average thicknesses of the spirotheca in the first to the seventh volution of eight specimens are 9, 11, 16, 25, 34, 48, and 47 microns, respectively. The proloculus wall is too thin to measure in most specimens, but it is near 9 microns thick.

The septa are almost plane throughout the length of the shell except that they are fluted in their lower margins in the extreme polar areas. Averages of the septal counts of the first to the fifth volution of three specimens are 10, 12, 13, 18, and 20, respectively. Septal pores are abundant.

The tunnel is narrow throughout the shell, and its path is about straight. Averages of the septal counts of the third to the sixth volution of five specimens are 25, 33, 42, and 39 degrees, respectively. The chomata are low and asymmetrical, with steep tunnel sides and low poleward slopes.

Remarks.—Triticites burgessae is one of the smallest of the species of the genus. In volume of shell it compares closely with *T. nebraskensis*. The possibility is recognized that *T. burgessae*, *T. nebraskensis*, and *T. pygmaeus* are dwarfed or stunted variations of larger species. This possibility has been discussed more thoroughly under the discussion of *T. nebraskensis*.

Triticites burgessae is more closely similar to *T. nebraskensis* than to any other species. It may possibly represent a geographic variation of that species. However, for the present, I am recognizing both of them. It is distinguished from *T. nebraskensis* by its slightly smaller proloculus, shorter and more inflated shell, and perhaps slightly less intensely fluted septa. Most measurable features of these two species are remarkably close.

Occurrence.—Triticites burgessae is exceedingly abundant in the Westerville shale of Iowa (I-59). The original type specimens came from the same locality.

TRITICITES NEBRASKENSIS Thompson
Pl. 28, fig. 11–20

Fusulina exigua STAFF, 1912, Zoologica, Heft 58, p. 39. ——, 1912, Palaeontographica, Bd. 59, p. 179–180, pl. 15, fig. 4. (Not *Fusulina vulgaris exigua* SCHELLWIEN, 1909)

Triticites exiguus DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, ser. 2, p. 111–113, pl. 8, fig. 1–5.

Triticites nebraskensis THOMPSON, 1934, Iowa Univ. Studies Nat. Hist., vol. 16, p. 281,282. NEEDHAM, 1937, New Mexico School Mines, Bull. 14, p. 30–32, pl. 4, fig. 2,3. THOMPSON & THOMAS, 1953, Wyoming Geol. Survey, Bull. 46, p. 29–31, pl. 2, fig. 20–33.

The shell of *Triticites nebraskensis* is minute in size and uniformly elongate fusiform in shape; with narrowly rounded to acutely pointed polar ends, low lateral slopes, and inflated central area. Some shells are subcylindrical in shape at maturity, with only slightly inflated central area, rounded polar ends, and straight to slightly irregular axis of coiling. Larger shells of five to six and a half volutions are 3.3 to 5.4 mm. long and 1.0 to 1.3 mm. wide, giving form ratios of 2.8 to 4.4. The shell changes shape with growth from a short ellipsoidal shell in the second and third volutions to a highly elongate subcylindrical or elongate fusiform shape at maturity. Averages of the form ratios of the first to the sixth volution of six specimens, including three topotype specimens, are 1.3, 1.9, 2.6, 3.1, 3.4 and 3.5, respectively.

The spirotheca is very thin but has a structure typical of the genus throughout the shell. Averages of the thickness of the spirotheca of the first to the sixth volution of six specimens are 10, 12, 18, 24, 38, and 50 microns, respectively. The spirotheca of the first two volutions is too thin to measure accurately, and the above measurements for those volutions are only close approximations. The proloculus wall is very thin and measures only about 9 microns.

The septa are thin and are moderately

widely spaced. They are fluted in the extreme polar ends but are about plane across the central two-thirds of the shell. The septal counts of the first to the sixth volution of two specimens are about 9, 12, 15, 17, 18, and 18, respectively. These figures agree closely with the figures given by Dunbar & Condra for the syntypes. Septal pores are very abundant especially in the polar regions.

The proloculus is minute, and its outside diameter measures 61 to 85 microns, averaging 72 microns for seven specimens. The shell expands at a uniform rate and the averages of the heights of the first to sixth volution of eight specimens are 27, 41, 58, 95, 140, and 162 microns, respectively.

The tunnel is narrow in the first three to four volutions, but it widens rapidly in the outer volutions. Averages of the tunnel angles of the third to the sixth volution of six specimens are 25, 31, 44, and 57 degrees, respectively. The chomata are distinct throughout all except the last volution. They are high and highly asymmetrical, with steep to overhanging tunnel sides and lower poleward slopes.

Remarks.—Staff (1910) figured a specimen from Iowa as *Fusulina exigua* and two years later described in detail and illustrated the same specimen as *F. exigua*. However, Schellwien (1909) had described a species from Darwas a few years earlier as *Fusulina vulgaris exigua*. Therefore, Staff created a homonym since subspecies have the same rank as species for nomenclatural purposes. Thompson (1934) proposed the name *Triticites nebraskensis* for this species and proposed to make the Nebraska specimens described and illustrated by Dunbar & Condra the types of *T. nebraskensis*. Through the kindness of Professor Dunbar I have had the opportunity to study a part of his original collection and part of them were employed in drawing up the above description.

Three minute species of *Triticites* have been described from the lower part of the Missourian Series, *T. nebraskensis*, *T. pygmaeus* Dunbar & Condra, and *T. burgessae* Burma. *T. nebraskensis* can be distinguished from *T. pygmaeus* by its smaller proloculus, more tightly coiled shell, and by its considerably larger form ratio. Also, the profile of the various volutions of its

Measurements of *Triticites nebraskensis* Thompson, in mm. (N-6, I-47)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions							Form ratio of volutions					
					1	2	3	4	5	6	7	1	2	3	4	5	6
1	3.3	1.0	3.2	.081	.023	.034	.055	.082	.143	.153	—	1.2	2.2	3.0	3.0	3.5	—
2	3.3	1.2	2.8	—	.020	.038	.052	.104	.135	.180	—	1.4	1.5	2.1	2.4	2.8	2.8
3	4.1	1.1	3.8	.063	.034	.045	.058	.100	.128	.162	—	1.0	1.9	2.3	2.7	3.9	3.8
4	5.0	1.2	4.1	.085	.026	.028	.047	.071	.110	.142	.170	1.5	2.0	3.0	4.6	4.0	4.4
5	5.4	1.2	4.4	.061	.024	.038	.060	.095	.142	.170	—	1.3	2.0	2.6	2.6	3.5	3.5
6	5.0	1.3	4.0	.073	.033	.048	.076	.132	.189	.189	—	1.3	1.8	2.5	3.5	4.0	4.0
7	—	1.0	—	.067	.029	.049	.056	.093	.140	—	—	—	—	—	—	—	—
8	—	1.1	—	.074	.030	.045	.060	.095	.123	.140	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca							Septal count						Tunnel angle					
	1	2	3	4	5	6	7	1	2	3	4	5	6	1	2	3	4	5	6
1	.008	.009	.013	.020	.043	.052	—	—	—	—	—	—	—	—	—	27	41	51	—
2	—	.012	—	.017	.033	.044	—	—	—	—	—	—	—	—	—	—	—	—	—
3	.008	.010	.018	.024	.037	.044	—	—	—	—	—	—	—	—	—	26	27	40	67
4	—	—	—	.016	.026	.038	.054	—	—	—	—	—	—	—	—	16	29	44	57
5	—	—	.017	.025	.033	.047	—	—	—	—	—	—	—	—	—	25	26	39	46
6	.011	—	.014	.022	.041	.061	.057	—	—	—	—	—	—	—	—	30	34	48	—
7	—	—	—	.014	.023	.036	—	10	13	15	15	17	—	—	—	—	—	—	—
8	.013	.011	.014	.017	.024	.039	.047	8	11	15	17	18	18	—	—	—	—	—	—

Specimens 1–3 are from collection N-6.

shell are more nearly symmetrical and uniform than are those of *T. pygmaeus*.

Triticites burgessae was described by Burma (1942) from the Westerville limestone of Iowa, only a few feet above the Cherryvale shale with numerous specimens of *T. nebraskensis*. Although the holotype of *T. burgessae* is much shorter than *T. nebraskensis*, some of Dunbar & Condra's original specimens of *T. nebraskensis* correspond closely with the holotype of *T. burgessae*.

Dunbar & Condra suggested that *T. nebraskensis* (*T. exiguus*) may represent a "dwarfed" form of a fusulinid living in a brackish water or at least muddy and somewhat unfavorable environment. This may be correct for, if representing distinct species, *T. burgessae*, *T. nebraskensis*, and *T. pygmaeus* all occur in highly argillaceous limestones or shales. However, *T. nebraskensis* has been recognized over a very large area in America and has been identified from New Mexico, Nebraska, Iowa, Missouri, and Wyoming. It does not seem likely that so distinct a species should be able to live in such abundance in unfavorable surroundings and still maintain such a wide distribution.

Occurrence.—Triticites nebraskensis is abundant in the Cherryvale shale of Iowa (I-6, I-47, I-49, I-52) and Missouri, in the Richfield Quarries of Nebraska (N-6), the Casper formation of Wyoming, and the Veredas group of New Mexico.

TRITICITES PYGMAEUS Dunbar & Condra
Pl. 28, fig. 8–10

Triticites cullomensis var. *pygmaeus* DUNBAR & CONDRA, 1928, Nebraska Geol. Survey, Bull. 2, Ser. 2, p. 95,96, pl. 5, fig. 3,4.
Triticites pygmaeus DUNBAR & SKINNER, 1937, Univ. Texas Bull. 3701, p. 614–616, pl. 48, figs. 13–26.

The shell of *Triticites pygmaeus* is minute in size, short, and inflated fusiform; with a straight axis of coiling in the first two to three volutions and irregular to shifting axis in the outer two or three volutions, narrowly rounded polar ends in the first three to five volutions, and blunt slightly extended polar ends in the outer one to three volutions. Mature shells of five and a half to six volutions are 3.4 to 4.5 mm. long and 1.5 to 1.8 mm. wide, giving form ratios of 2.3 to 2.7. The inner four and a half volutions have a rather uniformly ellipsoidal profile, but the outer volutions of most specimens have irregularly extended polar ends, resulting in an irregular profile. Average form ratios of the first to the sixth volution of five specimens are 1.4, 1.8, 2.3, 2.3, 2.5, and 2.5, respectively.

The proloculus is relatively large and has and outside diameter of 100 to 140 microns, averaging 119 microns for five specimens. The shell is relatively loosely coiled. The chambers are of about the same height throughout their width in the inner four volutions, but they become considerably higher in their end zones in the outer two volutions. Averages of the heights of the chambers in the first to the sixth volution of five specimens are 42, 63, 96, 140, 191, and 213 microns, respectively.

The septa are only slightly fluted in their extreme polar ends. Dunbar & Condra give a septal count of 11, 11 and 14, 14 and 15, 14 and 17, and 16 and 17 for the first to the fifth volution of two specimens.

The spirotheca is moderately thick and has a structure typical of the genus. Averages of the thickness of the spirotheca in

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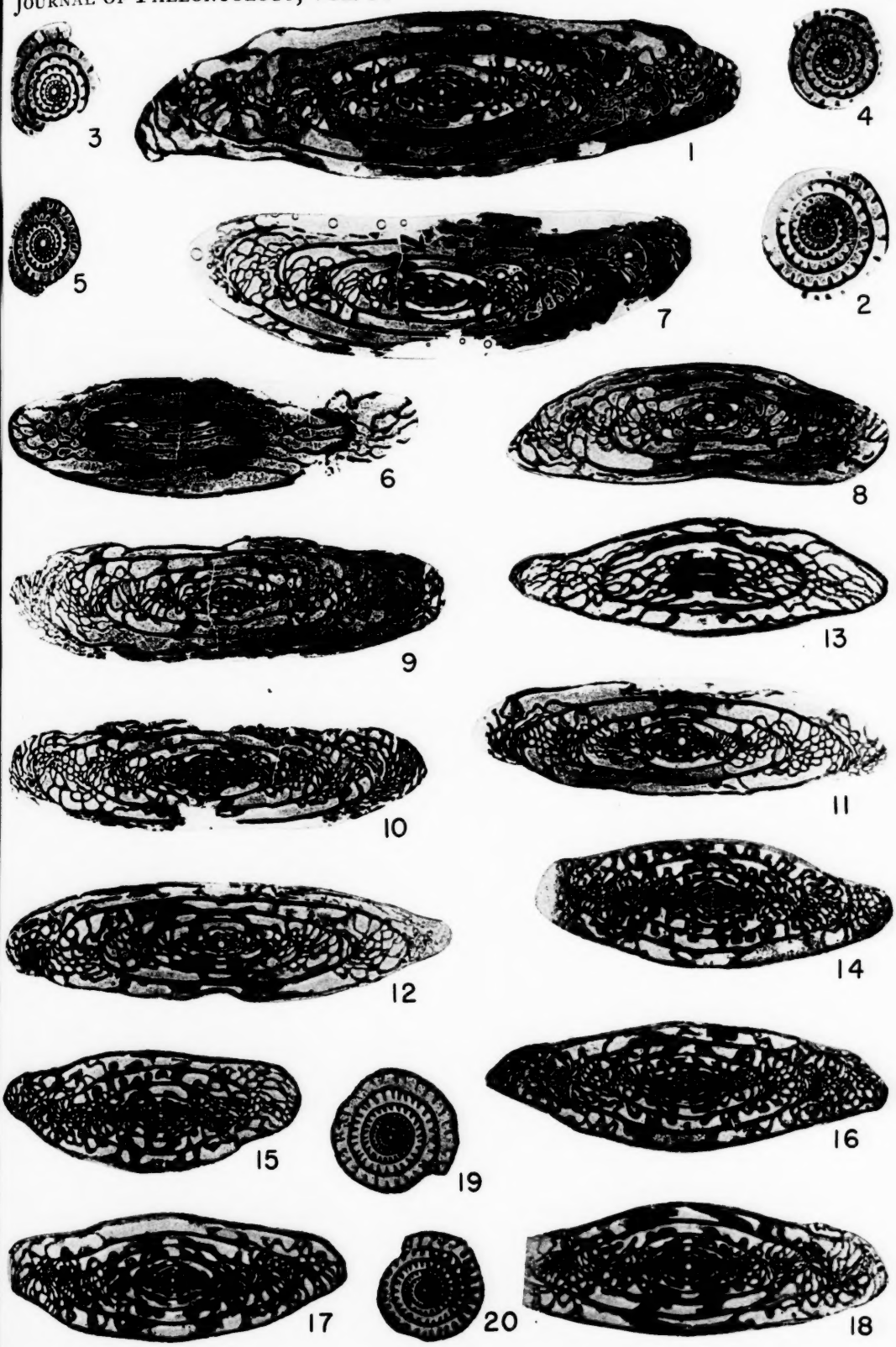
EXPLANATION OF PLATE 29

All illustrations on this plate are unretouched photographs, and all are magnified ×10.

FIG. *1–12—Triticites primarius* Merchant & Keroher. *1*, Axial section of the holotype; *2–5*, sagittal sections of topotypes; *6*, tangential section of a paratype; and *7–12*, axial sections of topotypes. Rock Lake shale member of the Stanton limestone (K-191). *3,4,5,7,8,9,10,11*, and *12* are of specimens 8, 10, 9, 7, 1, 6, 2, 3, and 5 of measurements.

13–20—Triticites newelli Burma. *13*, Tangential section of a topotype; *14–17*, axial sections of topotypes; *18*, axial section of the holotype; and *19,20*, sagittal sections of topotypes. South Bend limestone member of the Stanton limestone (K-215). *14,15,16,17,18,19*, and *20* are of specimens 3, 1, 5, 6, 9, 8, and 7 of measurements.



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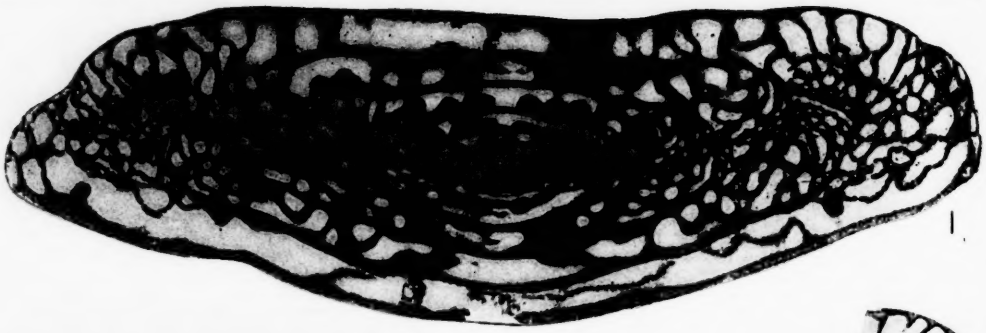
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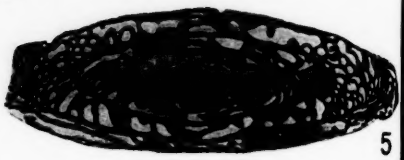
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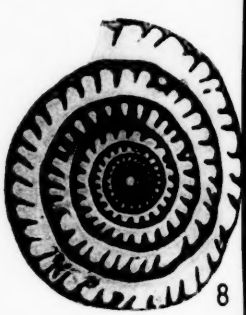
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M. L. Thompson

Measurements of *Triticites pygmaeus* Dunbar & Condra, in mm. (N-5)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions					
					1	2	3	4	5	6
1	4.5	1.7	2.6	.113	.050	.071	.120	.173	.229	.230
2	4.1	1.8	2.3	.142	.044	.066	.106	.135	.173	.218
3	3.9	1.6	2.4	.108	.044	.076	.101	.145	.205	.194
4	3.9	1.5	2.7	.102	.034	.048	.065	.117	.153	.193
5	3.4	1.5	2.3	.128	.039	.052	.088	.135	.196	.228

Specimen	Form ratio of volutions						Thickness of spirotheca					
	1	2	3	4	5	6	1	2	3	4	5	6
1	1.5	2.0	2.3	2.6	3.2	2.6	.010	.019	.021	.050	.068	—
2	1.3	1.8	2.6	2.5	2.6	2.3	.011	.015	.027	.035	.041	.061
3	1.2	1.8	2.2	2.1	2.2	—	.014	.016	.021	.031	.050	—
4	1.4	1.6	1.8	2.0	2.3	2.7	—	.014	.022	.034	.051	.053
5	1.6	2.0	2.1	2.4	2.3	—	.010	.014	.022	.039	.052	.070

Specimen	Tunnel angle (degrees)					
	1	2	3	4	5	6
1	—	—	30	32	42	43
2	—	—	21	30	36	56
3	—	—	25	37	47	—
4	—	—	30	36	43	—
5	—	—	26	37	40	—

the first to the sixth volution of five specimens are 11, 16, 23, 38, 55, and 61 microns, respectively. The proloculus wall measures about 12 microns.

The tunnel is narrow in the first two volutions, but it widens rapidly in the outer volutions. Averages of the tunnel angle of the third to the sixth volution of five specimens are 26, 34, 42, and 50 degrees, respectively. The chomata are high and broad, with steep tunnel sides, almost flat tops, and low poleward slopes. They spread laterally so as to reach the poles in the first three or four volutions and extend about half way to the poles with rapidly decreasing height in the outer two volutions.

Remarks.—Triticites pygmaeus was originally described by Dunbar & Condra as a variety of *T. cullomensis* Dunbar & Condra. However, it was later described by Dunbar & Skinner as a distinct species. The general shape of the shell of *T. pygmaeus* does resemble that of *T. cullomensis*, but it can be distinguished from that form by its minute size, thin spirotheca, relatively more massive chomata, and less uniform outer volution.

Triticites pygmaeus is one of the smallest species of the genus in America. Other species which correspond closely in size to it include *T. nebraskensis* and *T. burgessae*. All three of these are exceedingly abundant lo-

EXPLANATION OF PLATE 30

All illustrations on this plate are unretouched photographs.

FIG. *1–8—Triticites iatensis* Thompson, n. sp. *1*, Axial section of the holotype, ×20; *2*, axial section of the same, ×10; *3–5*, axial sections of paratypes, ×10; *6,7*, sagittal sections of paratypes, ×10; and *8*, sagittal section of a paratype, ×20. Iatan limestone of Missouri (M-37). *1(=2)*, *3,4,5,6*, and *7(=8)* are of specimens 2, 1, 4, 6, 7, and 8 of measurements.

9–16—Triticites kawensis Thompson, n. sp. *9–11*, Sagittal sections of paratypes; *12,13,15,16*, axial sections of paratypes; and *14*, axial section of the holotype; all ×10 from the Little Kaw limestone member (? South Bend limestone member) of the Stanton limestone (M-20). *10,11,14,15*, and *16* are of specimens 6, 5, 2, 1, and 3 of measurements.

cally in lower Missourian rocks and they may represent dwarfed or stunted variations of larger normal species. However, some of them are recognized over wide areas and are not considered to be abnormal variations of larger species.

Triticites pygmaeus can be distinguished from *T. nebraskensis* by its shorter shell, larger proloculus, thicker spirotheca, and more massive chomata. It differs from *T. burgessae* in most of the same features, except that its shell is much more elongate than that of *T. burgessae*.

Occurrence.—Triticites pygmaeus is abundant in the Lane shale of Nebraska from which the above described specimens were obtained. It has also been reported from the same stratigraphic level in Iowa, Missouri, and Kansas, in the Guernsey formation of Wyoming, and in the Gaptank formation of Texas. The above description is based on type specimens kindly sent to me by Professor Dunbar from Louisville, Nebraska (N-5).

TRITICITES PRIMARIUS Merchant & Keroher
Pl. 29, fig. 1–12

Triticites secalicus var. *primarius* MERCHANT & KEROHER, 1939, Jour. Paleont., vol. 13, p. 611–614, text-fig. 2–3, pl. 69, fig. 10–12.
Triticites primarius BURMA, 1942, Jour. Paleont., vol. 16, p. 748–749, pl. 118, fig. 1,8.

The shell of *Triticites primarius* is elongate subcylindrical in shape; with rounded polar ends, straight to slightly irregular or curving axis of coiling, and parallel to broadly convex lateral surfaces. Larger shells of six to seven volutions are 6.3 to 7.4 mm. long and 1.5 to 1.8 mm. wide, giving form ratios of 3.6 to 4.5. The first volution is elongate ellipsoidal in shape with highly convex lateral surfaces, but the axes of coiling rapidly elongate to give the shell a subcylindrical shape. Averages of the form ratios of the first to the sixth volution of seven topotype specimens are 1.6, 2.0, 2.5, 3.1, 3.3, and 3.5, respectively. The holotype of seven and a half volutions is 9.3 mm. long and 2.5 mm. wide, giving a form ratio of 3.7.

The proloculus is moderately large and has an outside diameter of 113 to 180 microns, averaging 144 microns for ten specimens. The shelf is moderately loosely coiled throughout. The chambers are lowest above the tunnel, and they increase in height gradually from there to near the polar ends where they increase in height sharply. Averages of the heights of the chambers above the tunnel in the first to the sixth volution of ten specimens are 53, 90, 115, 163, 179, and 251 microns, respectively.

The spirotheca is moderately thick for the size of the shell and is coarsely alveolar. It is thicker than that of most other Missourian species. Averages of the thickness of the spirotheca in the first to the sixth volution of ten specimens are 12, 21, 31, 48, 64, and 72 microns, respectively. The proloculus wall averages about 14 microns in thickness for ten specimens.

The septa are moderately widely spaced and contain a relatively thick pycnotheca. The septa of this species have about the best pronounced fluting of any Missourian species of the genus. They are fluted in their basal part in the end sixth of the shell but are about plane in the central shell area. Septal pores are very abundant in the polar areas, particularly in the sixth and seventh volutions. Averages of the septal counts of the first to the sixth volution of three specimens are 10, 16, 16, 18, 20, and 19, respectively.

The tunnel is very wide, is about two-thirds as high as the chambers and has a straight path. Averages of the tunnel angle of the first to the fifth volution of seven specimens are 38, 40, 54, 61, and 72 degrees, respectively. Near the center of the chambers the chomata are narrow and less than half as high as the chambers. Both slopes are steep but the tunnel slope is slightly the steeper.

Remarks.—Triticites primarius was originally described by Merchant and Keroher as a variety of *T. secalicus* (Say). It resembles that species closely. In fact, it resembles Douglas and lower Shawnee species of *Triticites* more closely than it does other Missourian species. It resembles *T. orizyformis* from the Westphalia limestone closely and can be distinguished from it by its larger proloculus, more loosely coiled shell, more nearly cylindrical shell at maturity, slightly less extensively fluted septa and thicker spirotheca.

Occurrence.—Triticites primarius is abundant in the Rock Lake shale exposed on the

Measurements of *Triticites primarius* Merchant & Keroher, in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						Form ratio of volutions					
					1	2	3	4	5	6	1	2	3	4	5	6
1	6.4	1.8	3.6	.172	.060	.090	.135	.198	.245	—	1.8	2.2	2.9	3.1	3.1	—
2	6.3	1.6	4.0	.133	.060	.080	.134	.170	—	—	1.5	1.9	2.5	3.2	3.7	—
3	6.3	1.8	3.6	.157	.059	.104	.114	.160	.210	—	1.5	2.0	2.5	3.3	3.6	—
4	—	—	—	.180	.055	.100	.135	.180	.231	—	1.3	1.6	2.2	2.8	2.9	—
5	7.4	1.8	4.2	.133	.042	.064	.099	.142	.152	.216	1.7	2.4	2.6	2.9	3.3	3.8
6	7.3	1.6	4.5	.148	.061	.081	.118	.183	.206	—	1.6	2.1	2.8	3.6	3.5	—
7	6.8	—	—	.113	.041	.063	.096	.129	.174	—	1.7	2.1	2.2	2.6	3.3	3.3
8	—	1.5	—	.113	.044	.066	.095	.145	.155	.247	—	—	—	—	—	—
9	—	1.5	—	.147	.053	.066	.089	.139	.195	—	—	—	—	—	—	—
10	—	1.4	—	.147	.060	.089	.137	.185	.224	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca						Septal count						Tunnel angle (degrees)				
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5
1	.014	.022	.036	.057	.073	—	—	—	—	—	—	—	48	65	66	64	67
2	—	.018	.030	.050	.067	.076	—	—	—	—	—	—	32	37	45	67	85
3	.011	.020	.040	.044	.069	—	—	—	—	—	—	—	22	26	50	65	83
4	.011	.028	.039	.057	.066	—	—	—	—	—	—	—	50	47	54	63	69
5	.012	.020	.022	.051	.060	.066	—	—	—	—	—	—	21	27	40	37	57
6	.013	.022	.033	.057	.068	—	—	—	—	—	—	—	44	42	61	64	74
7	.013	.017	.022	.030	.061	.074	—	—	—	—	—	—	47	46	59	70	—
8	.011	.017	.026	.034	.055	.074	10	14	13	14	16	19	—	—	—	—	—
9	.011	.019	.028	.040	.053	—	10	18	17	20	23	—	—	—	—	—	—
10	.012	.028	.038	.056	.070	—	9	17	19	19	20	—	—	—	—	—	—

south side of Little Sandy Creek just east of the bridge on the west side of the SW¼, Sec. 31, T. 26 S., R. 15 E., Woodson County, Kansas that is just above a limestone identified as the Stoner limestone member of the Stanton limestone (K-191, K-253). None of my collections from the Stanton of other areas contains specimens like this species.

TRITICITES NEWELLI Burma
Pl. 29, fig. 13–20

Triticites cf. *moorei* NEWELL, 1936, Jour. Geol., vol. 44, p. 29–31.
Triticites newelli BURMA, 1942, Jour. Paleont., vol. 16, p. 749–751, pl. 118, fig. 7,10.

The shell of *Triticites newelli* is small and uniformly fusiform in shape; with almost straight axis of coiling, convex to slightly irregular lateral slopes, and pointed polar ends. A typical specimen of seven and a half volutions is 5.8 mm. long and 2.0 mm. wide, giving a form ratio of 2.9. The first volution is subspherical in shape, and successive outer volutions gradually become less inflated with rapidly extending polar ends. The form ratios of the first to the seventh volution of the holotype specimen are 1.5, 1.7, 1.9, 2.0, 2.1, 2.4, and 2.8, respectively. Averages of the form ratios of the first to the eighth volution of seven specimens, including the holotype, are 1.3, 1.7, 1.9, 2.0, 2.1, 2.4, 2.8, and 2.8, respectively.

The proloculus is small and has an outside diameter of 78 to 122 microns, averaging 100 microns for ten specimens. The heights of the first to the seventh volution of the holotype specimen are 41, 74, 124, 144, 180, 232, and 230 microns, respectively. Averages of the heights of the chambers in the first to the seventh volution of ten specimens are 42, 61, 91, 122, 184, 240, and 248 microns, respectively. The chambers are of near the same height in the central half of the shell where the lateral slopes are of uniform convexity, but they are higher in the polar areas of outer volutions where the lateral slopes are more irregular.

The spirotheca is thin and distinctly alveolar. In the inner two volutions it is too thin to measure accurately. It is about 11, 14,

19, 28, 46, 60, and 78 microns thick in the first to the seventh volution, respectively, of the holotype. Averages of its thickness in the second to the seventh volution of ten specimens are 14, 19, 28, 46, 60, and 78 microns, respectively. The thickness of the spirotheca is greatest above the tunnel, and it thins gradually from there to the polar ends. The proloculus wall measures about 13 microns.

The septa are moderately widely spaced and are composed of thin pycnotheca. They are fluted rather broadly in the polar areas and in their lower margins to the tunnel borders. The septal count averages 11, 18, 22, 23, 25, and 31 in the first to the sixth

Measurements of *Triticites newelli* Burma, in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						
					1	2	3	4	5	6	7
1	5.0	1.9	2.6	.078 .110	.038	.050	.086	.121	.203	.256	—
2	4.4	1.9	2.3	.105	.037	.070	.104	.152	.190	.269	—
3	5.6	2.0	2.8	.083	.049	.057	.087	.095	.153	.224	.240
4	6.1	2.2	2.8	.086	.033	.057	.067	.102	.173	.274	.285
5	6.3	2.0	3.2	.075 .100	.049	.059	.088	.122	.181	.244	.264
6	5.8	2.0	2.9	.090	.034	.055	.070	.112	.165	.225	.247
7	—	1.7	—	.107	.049	.051	.076	.106	.178	.190	.221
8	—	2.0	—	.112	.049	.065	.101	.122	.172	.231	—
9	6.5	2.1	3.1	.122	.041	.074	.124	.144	.180	.232	.230
10	—	1.7	—	.115	.044	.070	.107	.143	.249	.252	—

Specimen	Form ratio of volutions								Thickness of spirotheca							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	1.2	1.7	1.7	1.7	1.7	2.0	—	—	.007	.013	.019	.029	.048	.046	—	—
2	1.2	1.4	1.8	1.8	1.9	2.1	—	—	.012	.013	—	.035	.043	.056	—	—
3	1.2	1.7	1.8	1.9	1.9	2.4	2.5	—	.009	.012	.016	.017	.036	.047	.081	—
4	1.4	1.7	1.7	2.0	2.1	2.4	2.4	2.8	—	.012	.016	.019	.037	.065	.062	.051
5	1.4	1.6	2.0	2.2	2.0	2.4	3.2	—	—	—	—	.033	.054	.072	.082	—
6	1.5	1.8	2.0	2.3	2.5	3.0	3.0	—	—	—	.014	.021	.036	.050	.068	—
7	—	—	—	—	—	—	—	—	—	.017	.021	.025	.046	.048	—	—
8	—	—	—	—	—	—	—	—	—	.015	.021	.034	.048	.066	—	—
9	1.5	2.1	2.1	2.2	2.4	2.8	3.1	—	.011	.015	.022	.037	.073	.086	.095	—
10	—	—	—	—	—	—	—	—	—	.015	.023	.031	.037	.068	—	—

Specimen	Septal count						Tunnel angle (degrees)						
	1	2	3	4	5	6	1	2	3	4	5	6	7
1	—	—	—	—	—	—	—	—	16	21	30	34	—
2	—	—	—	—	—	—	—	—	19	20	20	36	—
3	—	—	—	—	—	—	—	—	17	18	23	24	24
4	—	—	—	—	—	—	—	—	18	22	21	34	43
5	—	—	—	—	—	—	—	—	19	28	30	38	56
6	—	—	—	—	—	—	—	—	20	21	30	34	48
7	11	19	23	24	26	30	—	—	—	—	—	—	—
8	11	—	22	24	26	30	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	18	21	40	45	76
10	10	16	20	21	23	34	—	—	—	—	—	—	—

Specimen 9 is the holotype; specimen 10 the paratype.

volution, respectively, for three specimens. Septal pores are very abundant.

The tunnel has a relatively straight path, is more than half as high as the chambers, and becomes wide in the last volution. The tunnel angle averages about 18, 22, 28, 35, and 49 degrees, respectively, in the third to the seventh volution of seven specimens. The chomata are massive and broad, are more than half as high as the chambers, and have steep to overhanging tunnel sides and steep but spreading poleward slopes. They extend to the polar areas in the first three volutions and spread onto the septa for almost half the distance to the polar ends in the sixth and seventh volutions.

Remarks.—Triticites newelli is one of the more nearly uniform in profile of the Missourian *Triticites*, and it is a typical form of the genus in that its shell has a uniform profile throughout growth, its spirotheca increases in thickness throughout growth except for the last few chambers in some specimens, and its increase in size is uniform but gradual. It resembles somewhat closely the other two upper Missourian *Triticites* described below as *T. kawensis*, n. sp., and *T. iatensis*, n. sp. It can be distinguished from the first of these by its shorter and more uniform shell, smaller shell, larger and more broad chomata, more uniform septal fluting, and more tightly coiled outer volutions. *T. newelli* can be distinguished from *T. iatensis* by its smaller form ratios, thicker spirotheca in outer volutions, larger tunnel angles in outer volutions, and perhaps less extensive chomata deposits.

Triticites newelli was referred with question to *T. submucronatus* Thompson from the Hartville limestone and Casper formation of Wyoming by Thompson and Thomas (1953). However, studies of more extensive collections of topotype material of *T. newelli* indicate that, although these two forms are remarkably similar in general shell shape and other features, they probably are distinct and are so treated here. They can be distinguished by the more tightly coiled shell of *T. newelli*, its smaller proloculus, and its larger septal counts. Also, the chomata of *T. newelli* are more massive and larger.

Occurrence.—Triticites newelli is abundant in the South Bend limestone member of the Stanton limestone in Kansas (K-215) and is scarce in rocks of the same age referred to as the Little Kaw limestone member of the Stanton limestone of Missouri (M-20). The original type specimens and topotype specimens described above came from the South Bend of Kansas.

TRITICITES KAWENSIS, Thompson, n.sp.
Pl. 30, fig. 9–15

The shell of *Triticites kawensis* is elongate fusiform in shape and has straight to arcuate axis of coiling, pointed polar ends, and irregularly convex lateral surfaces. Larger shells of six and a half to eight volutions are 6.4 to 7.7 mm. long and 1.9 to 2.4 mm. wide, giving form ratios of 2.8 to 3.8. The first two to four volutions are short and highly inflated fusiform in shape, but the axial ends become greatly extended as maturity is approached, resulting in highly elongate fusiform mature shells. Averages of the form ratios of the first to the eighth volution of four specimens including the holotype, are 1.3, 1.6, 1.9, 2.3, 2.7, 3.0, 3.1, and 3.2, respectively.

The proloculus is small and has an outside diameter of about 75 to 125 microns, averaging 94 microns for six specimens. The shell is very tightly coiled for the first two volutions, is more inflated during the following three volutions, and becomes more highly inflated in the outer volution. Averages of the heights of the chambers near the middle of the first to the eighth volution of six specimens are 38, 57, 89, 135, 186, 239, 288, and 350 microns, respectively.

The septa are closely spaced in the inner three volutions and are of moderate spacing in outer volutions. Two specimens have an average septal count of 12, 17, 18, 22, 26, and 29 for the first to the sixth volution, respectively. The septa are fluted in the end quarters of the shell but are only slightly fluted in their lower margin near the center of the shell.

The tunnel is narrow in the inner four volutions but becomes moderately wide in outer volutions. Averages of the tunnel angles in the third to the seventh volution of four specimens are 23, 27, 31, 42, and 50 degrees, respectively. The chomata are more than half as high as the chambers to the sixth volution, but they become low in the outer volutions. Their tunnel sides are steep

Measurements of *Triticites kawensis*, n. sp., in mm. (M-20)

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions								Form ratio of volutions							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
1	6.4	1.9	3.4	.122	.041	.061	.104	.170	.227	.255	—	—	1.4	1.8	2.1	2.9	3.1	3.5	—	—
2	7.7	2.4	3.2	.076	.034	.031	.074	.113	.160	.236	.283	.330	1.0	1.1	1.8	2.2	2.6	3.1	3.3	3.2
3	6.4	2.3	2.8	.092	.032	.047	.071	.104	.170	.208	.302	.370	1.5	1.8	1.9	2.0	2.9	2.6	2.8	—
4	7.7	2.0	3.8	.100	.038	.066	.080	.122	.160	.217	.245	—	1.1	1.6	1.8	2.0	2.1	2.8	3.3	—
5	—	2.2	—	.087	.036	.069	.085	.132	.165	.236	.280	—	—	—	—	—	—	—	—	—
6	—	2.2	—	.090	.046	.068	.118	.170	.236	.283	.330	—	—	—	—	—	—	—	—	—

Specimen	Thickness of spirotheca								Septal count						
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7
1	—	.019	.029	.014	.047	.095	—	—	—	—	—	—	—	—	—
2	—	—	—	.028	.024	.069	.069	.059	—	—	—	—	—	—	—
3	—	—	.019	.030	.035	.061	.065	.071	—	—	—	—	—	—	—
4	—	—	—	.028	.047	.069	.074	—	—	—	—	—	—	—	—
5	—	—	.024	.031	.042	.057	.066	—	12	16	17	21	25	27	28
6	—	.012	.021	.033	.057	.064	.080	—	11	18	19	23	27	31	—

Specimen	Tunnel angle (degrees)						
	1	2	3	4	5	6	7
1	—	—	25	36	38	57	—
2	—	—	27	27	30	38	46
3	—	—	23	21	28	36	51
4	—	—	18	23	28	36	53
5	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—
9	—	—	23	27	31	42	50

throughout the shell, and their poleward slopes are low in the inner three to four volutions but are steep to vertical in outer volutions.

Remarks.—Triticites kawensis resembles *T. newelli* in some respects but can be distinguished from that species by its more elongate and irregular shell, larger shell, smaller and more narrow chomata, more irregularly fluted septa, and considerably more inflated outer volution.

Occurrence.—Triticites kawensis is one of the four typical *Triticites* here described from the upper part of the Missourian of Missouri and Kansas. The other three are *T. primarius* from the Rock Lake shale member of the Stanton limestone, *T. newelli* from the South Bend limestone of the Stanton, and *T. iatensis* from the Iatan limestone. This species is abundant in western Missouri (M-20). All four have not been found associated at the same place. However, *T. newelli* is represented by scarce specimens in the Little Kaw of Missouri.

TRITICITES IATENSIS, Thompson, n.sp.
Pl. 30, fig. 1–8

The shell of *Triticites iatensis* is of medium size and elongate fusiform shape; with a straight to slightly shifting or curving axis of coiling, slightly convex lateral slopes, and sharply pointed to rounded polar ends at maturity. The first volution is elongate ellipsoidal in shape, and the axial ends gradually become extended to the mature shape. Shells six and a half to seven and a half volutions measure 5.0 to 6.9 mm. long and 1.7 to 2.8 mm. wide, giving form ratios of 2.6 to 3.6 and averaging 3.2 for six specimens. Averages of the form ratios for the first to the seventh volution of six specimens are 1.8, 2.2, 2.4, 2.6, 2.9, 3.2, and 3.2, respectively.

The proloculus is minute in size and spherical in shape and has an outside diameter of 70 to 124 microns, averaging 94 microns for eight specimens. The shell expands slowly and about uniformly. Average heights of the chambers above the tunnel in the first to the seventh volution of eight specimens are 38, 57, 82, 119, 156, 210, and 238 microns, respectively. In most specimens the chambers are lowest above the tunnel, and they become higher gradually poleward and are highest as they reach the poles. In some they remain of near the same height in the central two-thirds of the shell and give the shell a subcylindrical shape.

The septa are closely spaced and are composed of thin pycnotheca. They are

moderately narrowly fluted in the polar regions and closed chamberlets extend more than half way to the tunnel. Only occasionally do the septa come in contact above the tunnel. The septa extend slightly forward in the tunnel region. Averages of the septal counts of the first to the seventh volution of two specimens are 12, 20, 22, 22, 26, 32, and 35, respectively.

The tunnel is slightly more than a third as high as the chambers, and its path is only slightly irregular. Averages of the tunnel angle in the third to the seventh volution of six specimens are 21, 25, 31, 40, and 38 degrees, respectively. Chomata occur throughout the shell except for the outer chambers and are more than half as high as the chambers, are rather broad, and extend along the septa as thick deposits above the tunnel and laterally to the polar regions where they appear as rather heavy axial fillings. In the inner four to five volutions the chomata extend as broad distinct ridges two-thirds as high as the chambers to the polar ends.

Remarks.—Triticites iatensis resembles several other species from near the Iatan limestone and doubtless is closely related to them, such as *T. orizyformis* Newell from the Westphalia limestone, *T. newelli* Burma

Measurements of *Triticites iatensis*, n. sp., in mm.

Specimen	L.	W.	Ratio	Diam. of prol.	Height of volutions						
					1	2	3	4	5	6	7
1	6.5	2.0	3.2	.090	.037	.066	.095	.148	.165	.228	.255
2	6.6	2.0	3.3	.070	.050	.061	.090	.110	.185	.201	.292
3	5.6	1.7	3.3	.089	.050	.068	.100	.143	.190	.217	—
4	5.0	1.9	2.6	.095	.031	.058	.082	.113	.126	.178	.268
5	6.9	1.9	3.6	.081	.031	.056	.066	.110	.146	.226	.234
6	6.2	1.9	3.3	.108	.042	.060	.089	.143	.162	.256	—
7	—	1.9	—	.124	.032	.044	.078	.100	.152	.181	.213
8	—	2.8	—	.096	.035	.041	.057	.088	.126	.196	.216

Specimen	Form ratio of volutions							Thickness of spirotheca						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	2.0	2.3	2.7	2.7	3.5	3.2	3.3	—	—	.016	.024	.048	.059	.059
2	1.7	1.8	2.0	2.2	2.5	3.0	3.4	—	—	—	.030	.046	.071	.065
3	2.4	2.5	2.3	2.7	3.1	3.6	—	—	—	.013	.031	.044	.056	—
4	1.6	2.3	2.7	2.8	2.7	2.7	2.7	—	—	.017	.029	.038	.047	.065
5	1.9	2.3	2.3	2.6	3.0	3.0	3.1	—	—	.016	.021	.032	.050	.064
6	1.5	2.0	2.5	2.3	2.8	3.4	3.4	—	—	.016	.024	.040	.053	.041
7	—	—	—	—	—	—	—	—	—	—	.020	.032	.050	.050
8	—	—	—	—	—	—	—	—	—	.014	—	.029	.052	.066

Specimen	Septal count							Tunnel angle (degrees)						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	—	—	—	—	—	—	—	—	—	22	26	32	35	—
2	—	—	—	—	—	—	—	—	—	22	26	29	51	—
3	—	—	—	—	—	—	—	—	—	22	25	31	40	—
4	—	—	—	—	—	—	—	—	—	22	24	26	42	32
5	—	—	—	—	—	—	—	—	—	20	23	30	37	44
6	—	—	—	—	—	—	—	—	—	17	24	38	34	—
7	14	22	21	23	28	35	35	—	—	—	—	—	—	—
8	11	18	22	22	25	30	35	—	—	—	—	—	—	—

from the South Bend shale of Kansas and *T. kawensis*, n. sp., from the Little Kaw limestone of Missouri. It can be distinguished from *T. kawensis* by its more tightly coiled shell, particularly in outer volutions, more nearly uniform lateral slopes, thinner spirotheca, more massive and extensive chomata, less intensely fluted septa, and more narrow tunnel angle in outer volutions. *Triticites iatensis* can be distinguished from *T. newelli* by its larger form ratio, thinner spirotheca in outer volutions, smaller tunnel angle in outer volutions, and more extensive chomata deposits. Also, the shell of *T. iatensis* is more nearly cylindrical in shape. *Triticites iatensis* resembles *T. orizyformis* in many respects.

Occurrence.—*Triticites iatensis* is common in association with much more abundant specimens of *Kansanella* (*Kansanella*) *joensis* in the Iatan limestone at St. Joseph, Missouri (M-18) and in the Iatan on U. S. Highway 71 southeast of St. Joseph (M-37). The above description and accompanying measurements are from the latter locality.

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UPPER CRETACEOUS FORAMINIFERA FROM NORTHERN IRELAND

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ABSTRACT—Foraminifera of Campanian-Maestrichtian age were obtained from the hollow flints of the topmost Cretaceous "Clay with Flints" deposit, and from previously unrecorded sources of foraminiferal material at similar levels on the north coast of Ireland. The microfauna of the condensed basal Cretaceous sandy succession is usually scarce and in poor condition; sufficient specimens are available to indicate horizons from Cenomanian to possibly Turonian at several localities and confirm megafossil evidence for age. The local paleogeographic interpretation suggests presence of a shallow water north-west "Greensand" basin and south-east "Greensand" basin, separated by a north-east/south-west basement ridge which was not crossed until the main "Chalk" transgression began.

INTRODUCTION

IN ORDER to establish reliable paleontological correlation with the Cretaceous rocks of England and northwestern Europe, previous collections of microfossils and megafossils from the Cretaceous of Northern Ireland have been re-examined and some of the fauna listed and figured. Much additional material has been collected in connection with the author's thesis at Queen's University.

Little previous work has been done on the Foraminifera; that published is almost confined to microfaunal lists and may be found in papers by Jones (1872), Wright (1874), Wright & Welch (1902), and Gough (1905). Of the more general publications dealing with the stratigraphy and megafauna of the North Irish Cretaceous, the most important are Portlock (1843), Tate (1865), Barrois (1876), Hume (1897), and Jukes Brown (1903).

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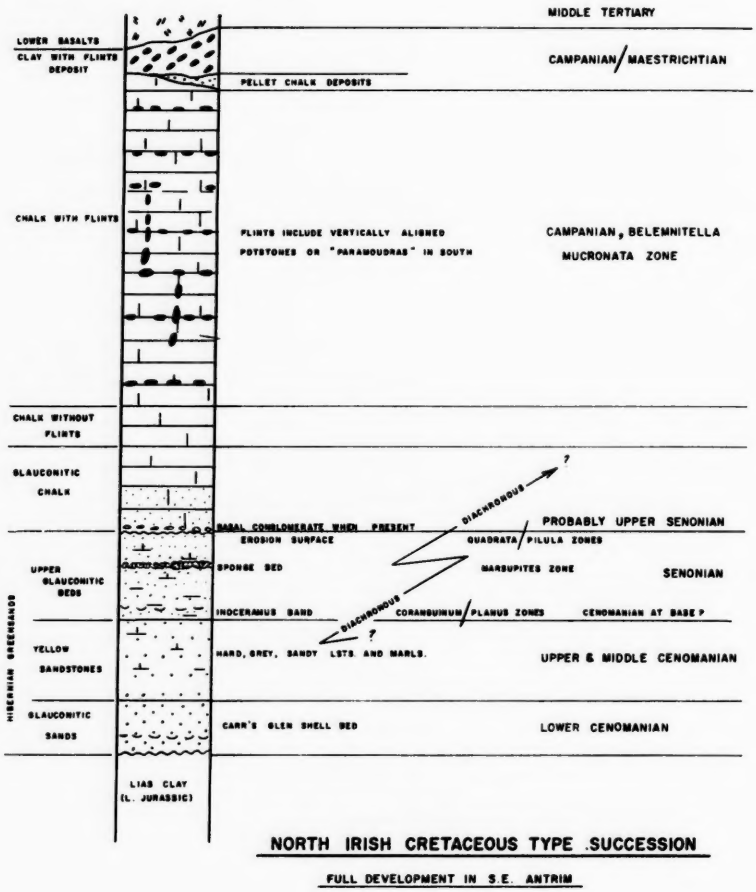
STRATIGRAPHY

The general Cretaceous succession in Northern Ireland is represented by Text-fig. 1, in the type area of southeastern Antrim. (Loc. 4–7). The succession is unconformable, resting on Lias clay in the south (Loc. 4–13) and in the north at Whitepark, Downhill



TEXT-FIG. *1*

and Magilligan (Loc. 28–32). It overlies Triassic beds at Lisburn (Loc. 2), Ballyeamon (Loc. 19), Murloch Bay (Loc. 24), Dungiven (Loc. 38) and Moneymore (Loc. 40–44). At Slieve Gallion outlier (Loc. 29) the basal Cretaceous boulder bed overlies Carboniferous sandstones, and at Knocklayd (Loc. 23) the basal Cretaceous conglomerate rests directly on Dalradian schists of the Pre-Cambrian. Almost all Cretaceous strata are flat lying or dip very gently, often towards the center of the plateau.

6. Clay with Flints

This deposit is present in greatly varying thickness, filling in irregularities at the top of the Chalk in many exposures. It seems unlikely that the unit is an entirely residual deposit of the Chalk (Jukes Brown 1906). The interiors of hollow flints from the Clay with Flints contain a soft powder with a rich microfauna; other flints from lower horizons usually contain only indurated Chalk.

The Ballycastle Pellet Chalk, (Loc. 25). The main exposure, which measures 40 ft. by 15 ft., is located on the sea cliff northwest of Ballycastle Harbor. It occupies a hollow in the top of the hard shattered Chalk, and is directly overlain by Tertiary basalt. The variation in grade of the soft pellety rock is very irregular in sub-angular units, presenting an appearance of partial current bedding combined with slip.

After fractionation, the material is found to consist of hard rounded chalk pellets, abundant angular flint fragments, and de-

rived Campanian-Maestrichtian Foraminifera, Bryozoa, etc., in a fine marly matrix. The characters of the exposure suggest deposition in some kind of channel in the top of the Chalk. Several other rather similar occurrences are known elsewhere on the north coast, where they are probably connected with explosive Tertiary vulcanism.

5. The Chalk

The Chalk outcrops around the margins of the overlying plateau basalts and nothing is known of the succession beneath the plateau. The surface thickness varies from 20 to 200 ft. and is greater in some boreholes near Coalisland (south of Loc. 45), reaching 480 ft. (Hartley, 1948).

In the Belfast area (Loc. 4–13) and in the North-West (Loc. 32–35) the Chalk is underlain by a variable Greensand series briefly described below. Elsewhere, in the North-East and South-West the basal beds are thin conglomerates and pebble beds resting directly on pre-Cretaceous strata.

The Chalk is a white compact pure carbonate, which is in places partly silicified. Its character, however, does not appear to be due to any action of the overlying basalts.

Bedded flints are common; in the South are found the vertically aligned, large pot-like flints known as "Paramoudras" (Buckland, 1817). The majority of the Chalk is included in the Campanian *Belemnitella mucronata* zone of Europe, although the basal portion in some cases belongs to lower zones, e.g., *Marsupites* zone at Whitepark (Loc. 28). The majority of the work on the megafauna has been done by Dr. J. M. Hancock of King's College, London.

4. The Basal Conglomerates

This basal unit consists of directly derived pre-Cretaceous elements in a hard glauconitic calcareous matrix. It is generally considered to herald the onset of the main upper Senonian transgression; at Moneymore (Loc. 40) a high Senonian form of *Echinocorys scutata* is found among the cobbles.

3, 2, and 1. The Hibernian Greensands

This group reaches its fullest development in the type-area of southeastern Antrim (Loc. 4, etc.). The maximum thickness reached is 60 ft.; the uppermost member is also represented in the North-West (Loc. 30–38). The group is discontinuous and variable; it contains several unconformities and disconformities, and is in general a diachronous condensed deposit.

(3) The Upper Glauconitic Beds

These consist of glauconitic limestones and calcareous glauconitic sands; the basal few feet often yield faunas typical of the Cenomanian, which do not appear to be derived. The *Inoceramus* band contains a rich brachiopod fauna of *Gibbythyris* and *Cretirhynchia* of species which belong to the *Holaster planus*—*Micraster coranguinum* zones of England, (highest Turonian-low Senonian). The "Sponge Bed" contains *Actinocamax verus* Miller and plates of *Uintacrinus-Marsupites* and can therefore be assigned to the *Uintacrinus-Marsupites* zone (lowest part of upper Senonian). Between the sponge bed and the overlying erosion surface, *Gonioteuthis granulata* (Blainville) and *G. quadrata* (Blainville) occur and the interval represents *Offaster pilula* to *G. quadrata* zones, (mid part of upper Senonian). The Chalk rests on different Greensand zones in different places, although no angular unconformity can be observed.

(2) The Yellow Sandstones

These variable beds consist for the most part of hard sandy argillaceous limestones and marls. *Acanthoceras* cf. *sherborni* Spath, *Mantelliceras* sp., *Schloenbachia* cf. *S. subtuberculata* (Sharpe), and brachiopods *Cyclothyris schloenbachi* (Dav.) *C. gallina* (Brongniart) indicate the upper-middle Cenomanian age of this member. A suite of Foraminifera from the highest beds on the east coast (Loc. 9–12) is probably not pre-Turonian (Gough, 1905)

(1) The Glauconite Sands

There is good evidence that these dark green argillaceous glauconite sands are lower Cenomanian in age. A rich shell bed in Carrs Glen (Loc. 7) contains *Schloenbachia subvarians* Spath, *S. intermedia* (Mantell), *S. subtuberculata* (Sharpe). The Cenomanian *Actinocamax primus* (Arkh.) also occurs at several localities. The above shell bed contains Foraminifera of several species which are characteristic of the Cenomanian.

PALEOGEOGRAPHY

The distribution of the pre-Chalk deposits can then be summarized as follows:

I. A northwest Greensand basin (Loc. 32–35). Zone 2 of Text-figure 2. Represented by Unit 3.
II. A broad northeast/southwest trend in which conglomerates are the basal beds (Loc. 19–28 and 39–40). Zone 3 of Text-figure 2. Represented by Unit 4.
III. A southeast Greensand basin of variable character (Loc. 4–12). Zone 1 of Text-figure 2. Represented by Units 1–3.

It seems that the pre-Cretaceous surface under (II) above formed a barrier which was not finally submerged until the main Chalk transgression took place. This positive area involves the Pre-Cambrian, against which progressive overlap of younger formations takes place.

TECHNIQUES

Chalk Powder from Hollow Flints

This material is usually soft and fossiliferous. The microfossils are fragile and difficult to obtain free from matrix as they are silicified. Gentle washing in water or boiling in water is sufficient to remove marly material. The residue is then sieved wet into grades and picked.

Ballycastle Pellet Chalk

This deposit contains a relatively rich, robust microfauna although some specimens are rather abraded by transport. The material is broken down as described for the Greensands, but less extensive treatment is necessary. Internal structures of individuals were observed by removal of the exterior of the test by means of dilute hydrochloric acid, and special serial sectioning methods were also used.

Greensands, Sandstones, etc.

It is usually necessary to break down this material to a sand by a recrystallisation or refrigeration method, or mechanically in a roller mill. The most successful chemical tried was sodium thiosulphate (common photographic hypo). The sample, if very hard, is first broken into moderate size pieces, placed in a hot concentrated solution of "hypo" in a metal pot, and boiled. On cooling, crystallizing forces fracture the rock fragments. The process is repeated until sufficient fine material is available for picking. The reduced samples are found to consist of quartz, glauconite, shell fragments, fine clay grains and a very sparse fauna of small Foraminifera in poor condition.

It was obviously desirable to find a method of concentrating the microfauna, but, although all known methods of separation were tried, none were successful as the density and flotation characteristics of the components were too nearly the same.

The Glauconite Sands

These samples were broken down by boiling in water. Some success in concentrating the Foraminifera was achieved by a panning method, using a shallow dish.

The Chalk

No method of extracting Foraminifera from this rock was found. Some thin sections were made, and in the Glauconitic Chalk some casts in glauconite were obtained.

STRATIGRAPHICAL ANALYSIS OF THE CAMPANIAN-MAESTRICHTIAN MICROFAUNA

The range chart shows the generalized European ranges of some of the more im-

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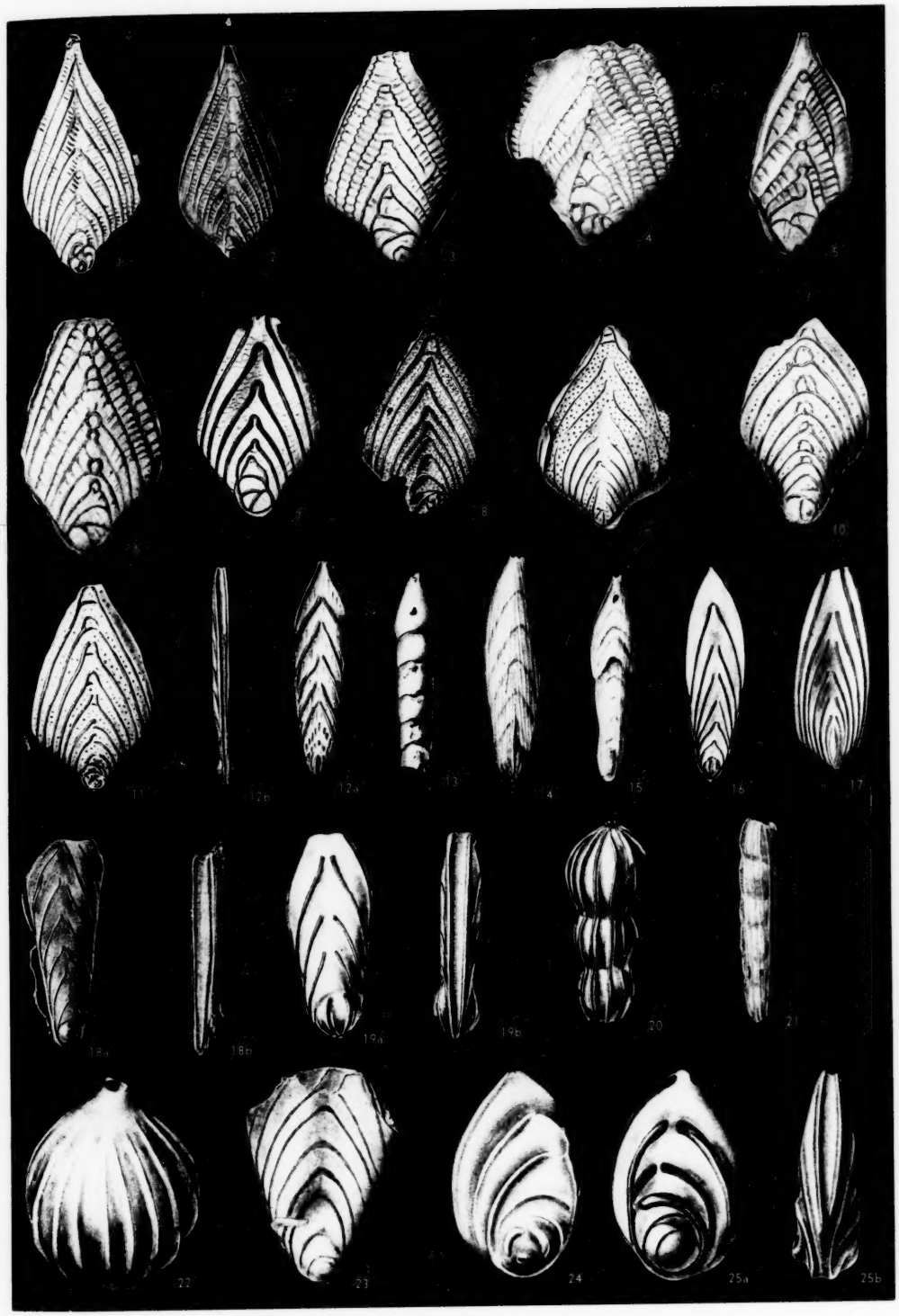
EXPLANATION OF PLATE 31

FIG. *1,2—Neoflabellina reticulata* (Reuss). *1*, C.H.SM-7, ×23; *2*, B.C.4-2, ×28½.
3–7—Neoflabellina praereticulata Hiltermann. *3*, B.C.6-7, ×47; *4*, B.C.4-1a, ×52½; *5*, B.C.4-1b, ×52½; *6*, B.C.4-1c, ×52½; *7*, B.C.6-7, ×40½.
8–11—Neoflabellina rugosa (d'Orbigny). *8*, C.H.SM-8, ×36; *9*, B.C.SM-2, ×40½; *10*, B.C.9-13, ×24½; *11*, B.C.SM-1, ×30½.
12—Frondicularia striatula Reuss. B.C.SM-9, ×9½.
13—Frondicularia lanceola Reuss. C.H.SM-10, ×21.
14,15—Frondicularia cf. *F. affinis* Marsson. *14*, C.H.SM-12, ×21; *15*, C.H.SM-11, ×22½.
16—Frondicularia clarki Bagg. B.C.SM-3, ×20½.
17—Frondicularia watersi Cushman. B.C.SM-4, ×40½.
18—Frondicularia archiaciana d'Orbigny. B.C.4-3, ×22½.
19—Frondicularia linearis Franke. B.C.SM-5, ×26.
20,21—Nodosaria affinis Reuss. *20*, C.H.SM-13, ×23; *21*, B.C.4-17, ×18.
22—Lagena cf. *L. cayeuxi* Marie. B.C.A.50, ×78½.
23—Palmula cf. *P. cordata* Reuss. B.C.4-4, ×11.
24,25—Palmula robusta Brotzen. *24*, C.H.SM-14, ×27; *25*, B.C.SM-6, ×33½.



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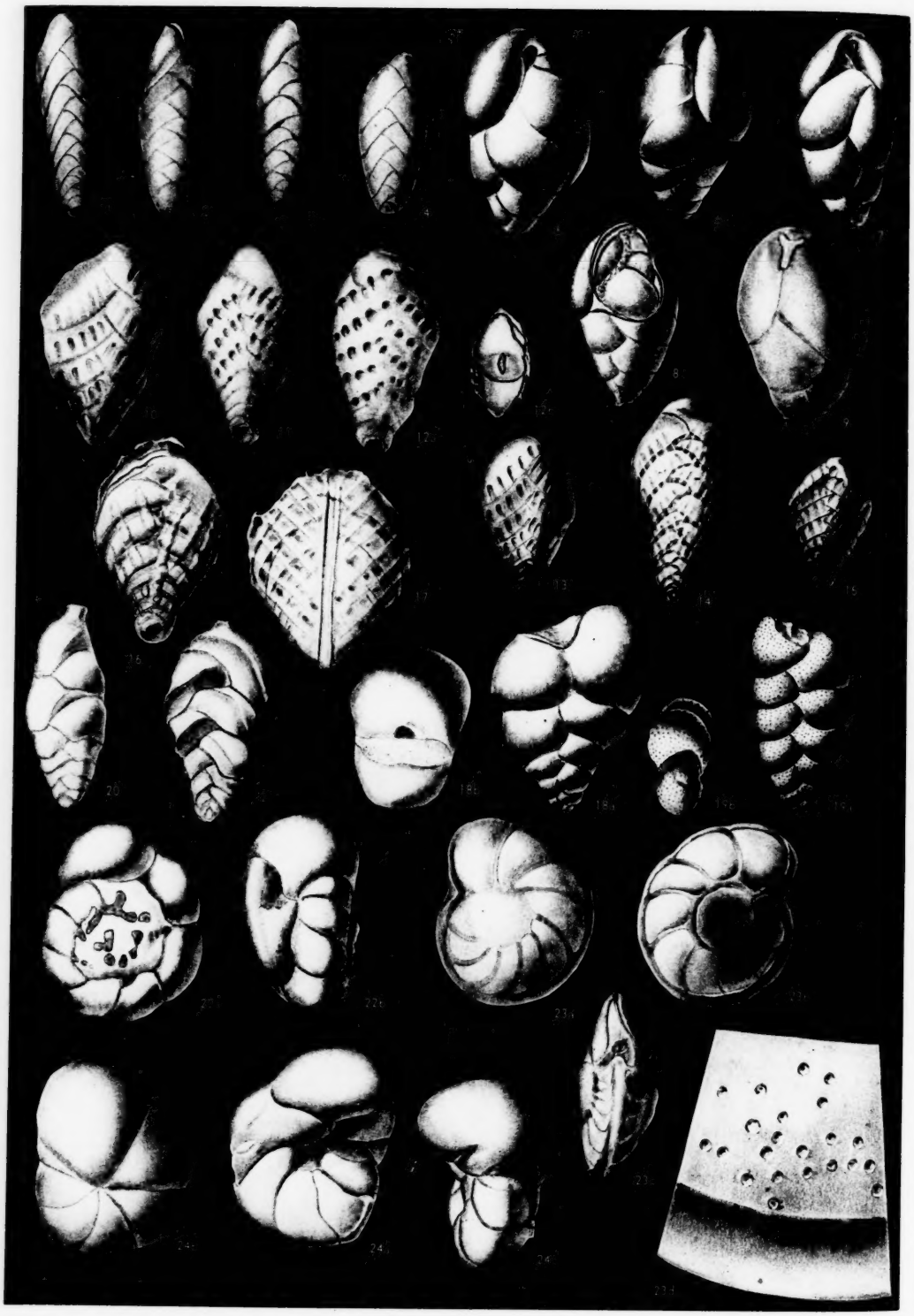

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portant Foraminifera which occur in the Cretaceous rocks of Northern Ireland. The Campanian-Maestrichtian microfauna falls into three broad groups:

1. Maestrichtian only (2 species)
2. Campanian-Maestrichtian (13 species; there are many more)
3. Campanian only (2 species)

The two Maestrichtian species, *Neoflabellina reticulata* (Reuss), *s.s.*, and *Palmula robusta* Brotzen, have not been found, in the variants specified, below the lowest Maestrichtian (*Belmnitella lanceolata* beds) in Europe.

In like fashion neither of the two species *Globorotalites conicus* Carsey and *Neoflabellina rugosa* (d'Orbigny) are known post-Campanian.

In the Ballycastle Pellet Chalk most of the forms in the 2nd and 3rd categories may be found in one sample. The two forms from the first category are only found in the highest flints of the Clay with Flints deposit. It may thus be assumed that the Ballycastle Pellet Chalk and some elements of the Clay with Flints contain assemblages from high Campanian-low Maestrichtian levels. However, Dr. Heinrich Hiltermann has recently confirmed my tentative identification of Ballycastle material as *Osangularia lens* Brotzen, a Maestrichtian index in northern Germany. Other elements of the Clay with Flints contain assemblages from higher levels in the Maestrichtian, corresponding to horizons not now represented *in situ*.

MICROFAUNAL LISTS

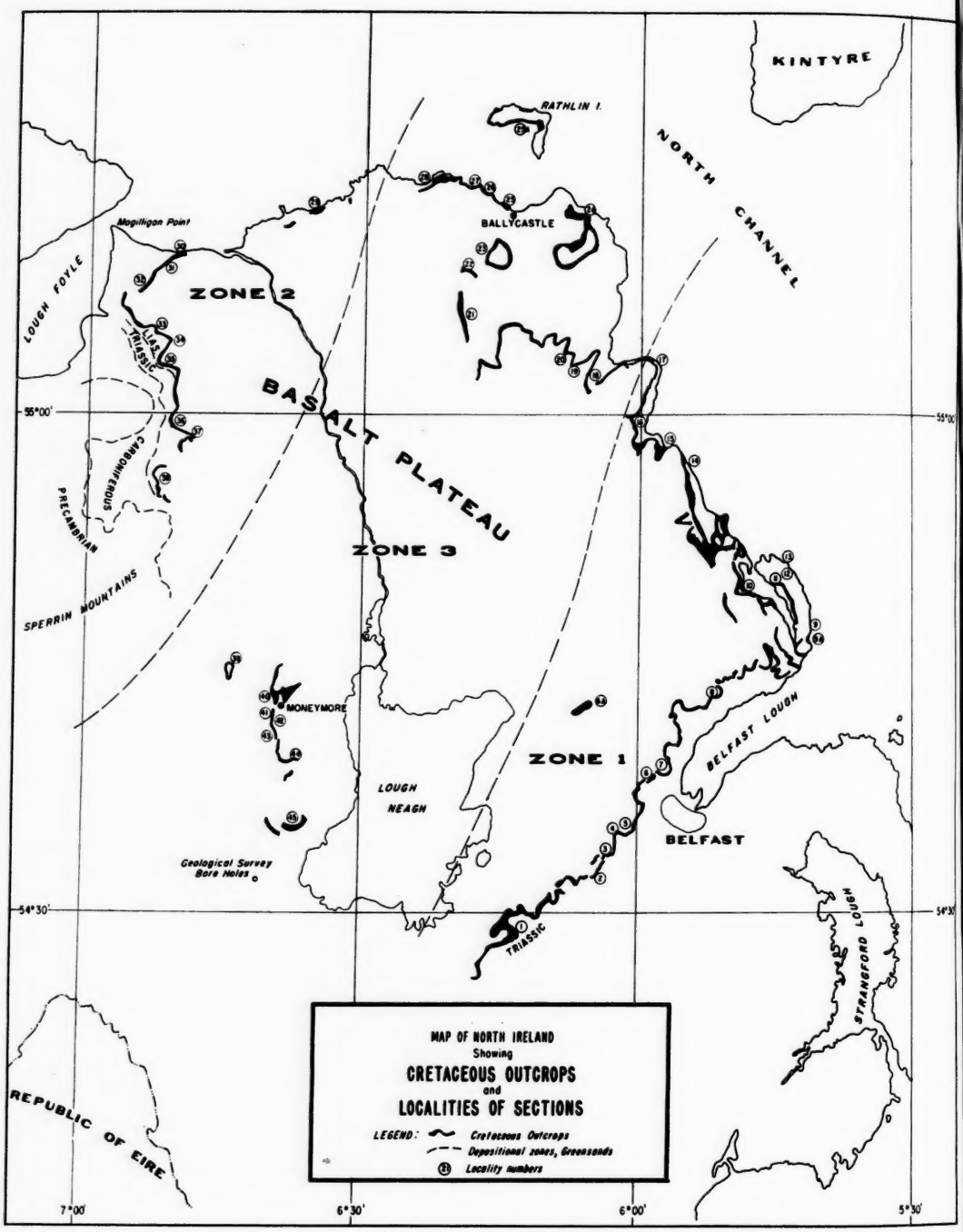
Campanian-Maestrichtian

The following are some of the Foraminifera found in the derived deposits and in the hollow flints of the Clay with Flints deposit:

Ammodiscus cretaceus (Reuss)
Spiroplectammina dentata (Alth)
Spiroplectammina laevis cretosa Cushman
Spiroplectammina sp.
Textularia cf. *T. ripleyensis* Berry
Textularia cf. *T. baudouiniana* d'Orbigny
Gaudryina spp.
Siphogaudryina cf. *S. foveolata* (Marsson)
Verneuilina limbata Cushman
Verneuilina sp.
Arenobulimina cf. *A. ovoidea* Marie
Ataxophragmium subsphaerica (Marie)
Eggerella tribullata von Hagenow
Hagenowella elevata d'Orbigny
Marssonella oxycona Reuss
Orbignyna ovata von Hagenow
Orbignyna cf. *O. variable* d'Orbigny
Plectina ruthenica Reuss
Neoflabellina reticulata (Reuss)
Neoflabellina praereticulata Hiltermann
Neoflabellina rugosa (d'Orbigny)
Neoflabellina rugosa leptodisca (Wedekind)
Frondicularia affinis Marsson
Frondicularia angustissima Reuss
Frondicularia archiaciana d'Orbigny
Frondicularia cf. *F. clarki* Bagg
Frondicularia cordai Reuss
Frondicularia lanceola Reuss
Frondicularia linearis Franke
Frondicularia linguiformis Marsson var.
Frondicularia ogivalis Marie
Frondicularia striatula Reuss
Frondicularia watersi Cushman var.
Lenticulina spp., including
L. rotulata Lamarck
Marginulina cf. *M. austiniana directa* Cushman
Marginulina trilobata d'Orbigny
Vaginulina cf. *V. geinitzi* Reuss
Enantiovaginulina recta d'Orbigny
Vaginulinopsis sp.
Palmula robusta Brotzen
Dentalina spp.
Dentalina gracilis d'Orbigny
Nodosaria spp.
Nodosaria affinis Reuss
Lagena cf. *L. cayeuxi* Marie
Guttulina communis (d'Orbigny)
Guttulina problema (d'Orbigny)
Polymorphina acuminata d'Orbigny
Ramulina globulifera cretacea Schacko

EXPLANATION OF PLATE 32

FIG. *1–4—Bolivina incrassata* Reuss. B.C.4-23, ×38½.
5–8—Buliminella obtusa (d'Orbigny). B.C.9-10, ×57.
9—Buliminella cf. *B. obtusa* (d'Orbigny). B.C.4-25, ×39.
10–15—Bolivinoides decoratus Jones, s.s. *10*, B.C.9-9, ×52½; *11*, B.C.4-21, ×54; *12*, B.C.4-21, ×54; *13*, B.C.9-9, ×52½; *14*, B.C.6-1, ×84½; *15*, B.C.9-9, ×52½.
16—Bolivinoides cf. *B. draco* Marsson. B.C.4-22, ×78½.
17—Bolivinoides draco draco Hilt. & Koch. B.C.6-2, ×90½.
18,19—Gümbelina globulosa (Ehrenberg). *18*, B.C.9-14, ×102½; *19*, B.C.6-5, ×66½.
20,21—Eouvigerina cretacea H-1 & Earland. B.C.A.-38; *20*, ×117; *21*, ×126.
22—Anomalina pseudoexcolata Kalinin. B.C.9-15, ×40½.
23—Cibicides voltziana d'Orbigny. B.C.5-13, ×38; *23d*, pores on ventral side near margin, ×262½.
24—Cibicides beaumontianus (d'Orbigny). B.C.5-17, ×51.


KINTYRE
RATHLIN I.
NORTH CHANNEL
BALLYCASTLE
Magilligan Point
LOUGH FOYLE
ZONE 2
BASALT PLATEAU
ZONE 3
ZONE 1
LIAS
TRIASSIC
CARBONIFEROUS
PRECAMBRIAN
SPERRIN MOUNTAINS
MONEYMORE
LOUGH NEAGH
BELFAST LOUGH
BELFAST
Geological Survey Bore Holes
TRIASSIC
STRANGFORD LOUGH
REPUBLIC OF EIRE
55°00'
54°30'
7°00'
6°30'
6°00'
5°30'
MAP OF NORTH IRELAND
Showing
CRETACEOUS OUTCROPS
and
LOCALITIES OF SECTIONS
LEGEND: Cretaceous Outcrops
Depositional zones, Greensands
Locality numbers

TEXT-FIG. 2

Ramulina cf. *R. brachiata* Jones
Bolivinoides decorata decorata Jones
Bolivinoides draco Marsson
Bolivinoides draco militaris Hiltermann & Koch
Bolivinitella eleyi (Cushman)
Eouvigerina cretacea (Heron-Allen & Earland)
Gümbelina globulosa Ehrenberg
Bolivina incrassata Reuss
Buliminella obtusa (d'Orbigny)
Buliminella laevis (Beissel)
Loxostoma plaitum Carsey
Loxostoma sp.
Pleurostomella subnodosa (Reuss)
Eponides beisseli Schijfsma
Eponides spp.
Gyroidina umbilicata d'Orbigny
Gyroidinoides nitida (Reuss)
Gyroidinoides globosa (von Hagenow)
Stensioina pommerana (Brotzen)
Stensioina exsculpta (Reuss)
Stensioina sp.
Pullenia cretacea Cushman
Pullenia cf. *P. coryelli* White
Pullenia jarvisi Cushman
Pullenia cf. *P. quinqueloba* (Reuss)
Globigerina cretacea d'Orbigny
Globigerinella aspera (Ehrenberg)
Globorotalites conicus (Carsey)
Globotruncana arca Cushman
Globotruncana rugosa Marie
Globotruncana ventricosa Brotzen [non White]
Globotruncana sp.
Anomalina clementiana d'Orbigny
Anomalina pseudoexcolata (Kalinin)
Cibicides excavata Brotzen
Cibicides voltziana d'Orbigny
Gavelinella pertusa (Marsson)

Basal Chalk and Upper Glauconitic Beds (*Senonian-?Turonian*).

Gümblina globulosa Ehrenberg
Bolivinitella eleyi (Cushman)
Globorotalites micheliniana (d'Orbigny)
Bulimina, Globigerina, Verneuilina, Globotruncana, spp.

} mainly from glauconitic casts and thin sections

Basal Glauconite Sands (*Lower Cenomanian*).

Tritaxia macfadyeni Cushman
Tritaxia pyramidata Reuss
Citharinella sp.
Saracenaria cf. *S. italica* Defrance
Vaginulina cf. *V. ichenbergi* Terquem
Lenticulina, Marginulina, Vaginulina and *Nodosaria* spp.
Eoguttulina anglica Cushman & Ozawa
Gavelinella sp.

Key to abbreviations and depository references:

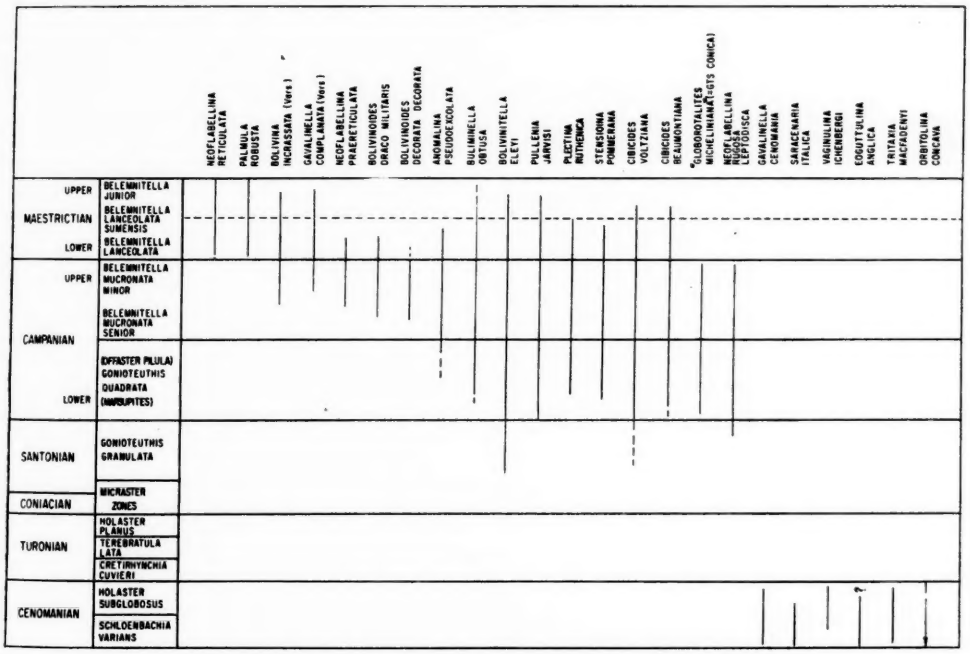
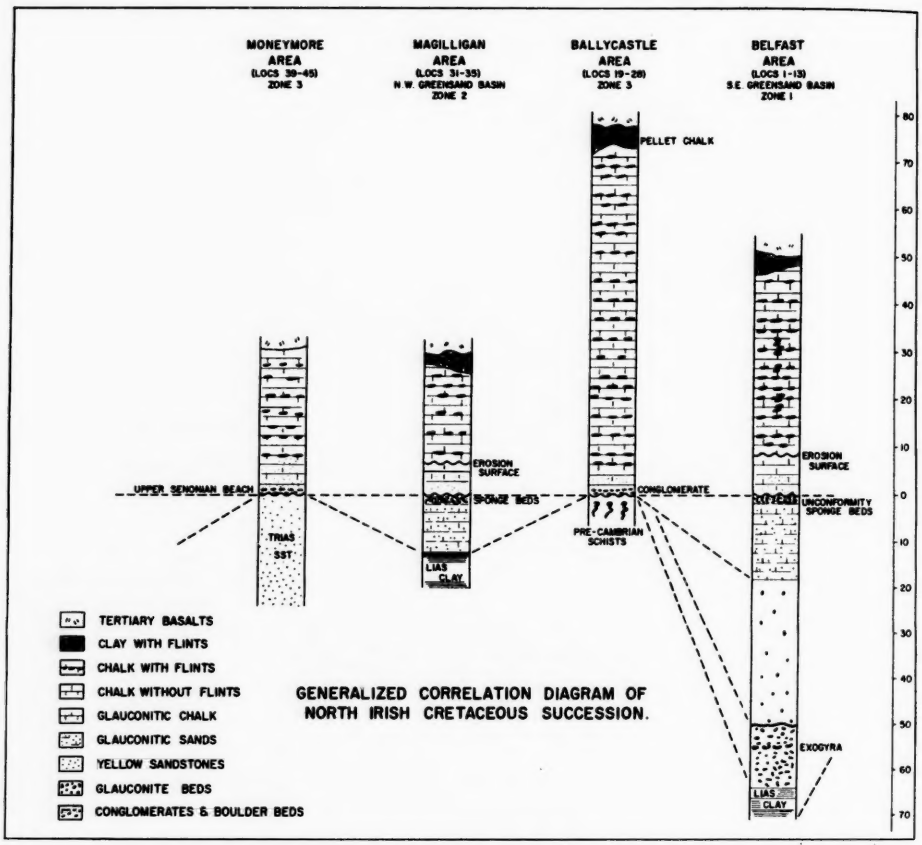


CHART SHOWING EUROPEAN RANGES OF SOME FORAMINIFERA WHICH OCCUR IN N. IRELAND
(COMPILED FROM VARIOUS SOURCES)

TEXT-FIG. *3*



TEXT-FIG. 4

B.C.—from Ballycastle "Pellet Chalk"
C.H.—from hollow flints in Clay with Flints deposit
SM—Sedgwick Museum, University of Cambridge. No. 779
B.C.4, B.C.5, B.C.6, B.C.9—The Queen's University of Belfast, Department of Geology
A—Author's Collection—some of these types are to be deposited in the American Museum of Natural History

SYSTEMATIC PALEONTOLOGY

Family AMMODISCIDAE
Genus AMMODISCUS Reuss, 1861
AMMODISCUS CRETACEUS (Reuss)
Pl. 34, fig. 9

Operculina cretacea REUSS, 1845, Die Versteinerungen der böhmischen Kreideformation (Stuttgart), vol. 1, p. 35, pl. 13, fig. 64,65.
Cornuspira cretacea REUSS, 1860, Kaiser. Akad. Wissen. Naturwiss. Sitz., (Wien), vol. 40, p. 177, pl. 1, fig. 1.
Cornuspira involvens (Reuss) BERRY, 1929, in Berry & Kelley, U. S. Nat. Mus. Proc., vol. 76, pt. 19, p. 15, pl. 1, fig. 15.
Ammodiscus cretacea (Reuss) CUSHMAN, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, pt. 2, p. 44–47, (synonymy).
Ammodiscus cretaceus (Reuss) CUSHMAN, 1944, Contr. Cushman Lab. Foram. Res., vol. 20, pt. 1, p. 2, pl. 1, fig. 2; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 17,18, pl. 1, fig. 35 (synonomy); FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 58, pl. 1, fig. 15.

Test planispiral, closely coiled, only slightly involute; chamber increasing uniformly in size, about ten revolutions, often showing radial ridging and constriction; suture distinct, depressed; wall finely arenaceous; aperture occupies open end of tube.

Range and distribution.—The species has a wide range in the Cretaceous of Europe and the U. S.

Hypotype.—Queen's University, Belfast, B.C. 5-34.

FAMILY TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA DENTATA (Alth)

Textularia dentata ALTH, 1850, Haidinger's Nat. Abh., vol. 3, p. 262, pl. 13, fig. 13.

Spiroplectammina dentata (Alth) CUSHMAN & JARVIS, 1932, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 14, pl. 3, fig. 7; —— & ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 27, pl. 5, fig. 11.

Test compressed, periphery rather acute; chambers distinct, low and broad, twenty-five to thirty visible, increasing slightly in height but rapidly in breadth; sutures distinct, only very slightly curved, slightly depressed; wall finely arenaceous, smooth.

Range and distribution.—Described by Alth from the Upper Cretaceous of central Europe.

Hypotype.—Author's collection, B.C. 78.

SPIROPLECTAMMINA LAEVIS (Roemer) var. CRETOSA Cushman

Pl. 34, fig. 8a,b

Spiroplectammina semicomplanata (Carsey) PLUMMER [part], 1931, Univ. Texas Bull., vol. 3101, p. 127, pl. 8, fig. 8, [not fig. 7].

Spiroplectammina laevis (Roemer) *var. cretosa* CUSHMAN, 1932, Contr. Cushman Lab. Foram. Res., vol. 8, p. 87, pl. 11, fig. 3; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 27,28, pl. 6, fig. 1–3, (synonymy).

Test tapering, longer than broad, periphery rather acute; sutures distinct, rather straight; chambers shallow, about twenty-five visible in adult; Cushman, 1946, "the margin of the apertural face distinctly raised, giving a series of raised ridges at the suture lines and forming a raised zigzag line along the center of the test . . . "; wall finely arenaceous, smooth; aperture a low opening on the inner margin of the apertural face.

Range and distribution.—The type specimen of the variant is from the upper part of the Taylor marl.

Hypotype.—Author's Collection, B.C. 79.

Family VERNEUILINIDAE

Genus VERNEUILINA d'Orbigny, 1840

VERNEUILINA LIMBATA Cushman

Pl. 34, fig. 4

Verneuilina limbata CUSHMAN, 1936, Contr. Cushman Lab. Foram. Res., Spec. Publ., No. 6, p. 2, pl. 1, fig. 2; ——, 1937, Contr. Cushman Lab. Foram. Res., Spec. Publ., No. 7, p. 12, pl. 1, fig. 21.

Test elongate, triangular in section, tapering; sides flat to concave; chambers distinct, not markedly raised, strongly curved; wall finely arenaceous, smooth; aperture a sharp loop-shaped opening at the inner margin of the apertural face.

Range and distribution.—The type specimen is from the Craie blanche of France; the species is characteristic of the upper Senonian of Europe, occurring abundantly in the Campanian.

Hypotype.—Queen's University, Belfast, B.C. 9-12.

Family VALVULINIDAE

Genus PLECTINA Marsson, 1878

PLECTINA RUTHENICA (Reuss)

Plectina ruthenica (Reuss) CUSHMAN, 1937, Contr. Cushman Lab. Foram. Res., Spec. Publ., No. 8, p. 105, pl. 11, fig. 10, (synonymy).

Test elongate, slightly compressed; earliest whorl with several chambers, apparently about four, later triserial and biserial rapidly; late formed chambers become rather displaced tending towards a terminal position; early chambers indistinct, later distinct, inflated; wall arenaceous; aperture terminal, rounded or elliptical.

Range and distribution.—The type is from the Upper Cretaceous of Limburg. The species is common in the Senonian of Europe and is abundant in Rugen.

Hypotype.—Author's Collection, C.H. 55.

Genus MARSSONELLA Cushman, 1933

MARSSONELLA OXYCONA (Reuss)

Pl. 33, fig. 8

Gaudryina oxycona REUSS, 1860, Kaiser. Akad. Wissen. Naturwiss. Sitz., (Wien), vol. 40, p. 229, pl. 12, fig. 3.

Marssonella oxycona (Reuss), CUSHMAN, 1933 [part], Contr. Cushman Lab. Foram. Res., vol. 9, p. 36, pl. 4, fig. 13a,b; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 43,44, pl. 12, fig. 3–5, (synonymy, in part only); FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 75, pl. 6, fig. 17.

Test conical, tapering rapidly; first whorl with four chambers, rapidly becoming biserial; transverse section round; chambers fairly distinct, not inflated, not sub-divided; sutures fairly distinct, flush with surface of the test; wall finely arenaceous; aperture a broad low curved opening at the inner margin of the apertural face.

Range and distribution.—The species is

common in the Upper Cretaceous of Europe, and also occurs in the Taylor and Austin groups in the U.S.A.

Hypotype.—Queen's University, Belfast, B.C. 9-11.

Family LAGENIDAE

Genus NEOFLABELLINA Bartenstein, 1949

NEOFLABELLINA PRAERETICULATA Hiltermann

Pl. 31, fig. 3–7

N. praereticulata is a species set up by Hiltermann to include forms in a morphogenetic series [*N. rugosa* (d'Orbigny), *N. praereticulata* Hiltermann, *N. reticulata* (Reuss)] earlier than *N. reticulata*, sensu stricto. *N. praereticulata* carries punctate ornament in the early stages of the test developing reticulate ornament in the later stages; this reticulate ornament is rather less dense and regular than that of *N. reticulata sensu stricto.*

Range and distribution.—*N. praereticulata* ranges through the upper Campanian to Maestrichtian.

Hypotype.—Queen's University, Belfast, B.C. 6-7.

NEOFLABELLINA RETICULATA (Ruess)

Pl. 31, fig. 1, 2

Flabellina reticulata REUSS, 1851, Haidinger's Nat. Abh., vol. 4, pt. 1, p. 30, pl. 1, fig. 22; BARTENSTEIN, 1948, Senckenbergiana, vol. 28, pt. 4–6, p. 124.

Flabellina favosa BEISSEL, 1891, K. Preuss. Geol. Landes. Abh., (Berlin), vol. 3, p. 49, pl. 19, fig. 25–28, pl. 26, fig. 28.

Frondicularia reticulata (Reuss) BAGG, 1898, U. S. Geol. Sur. Bull., No. 88, p. 50, pl. 13, fig. 6.

Flabellina cf. *F. interpunctata* (v.d. Marck) CUSHMAN, 1926, Bull. Amer. Assoc. Petrol. Geol., vol. 10, pt. 6, p. 598, pl. 20, fig. 6.

Palmula reticulata (Reuss) CUSHMAN & TODD, 1943, Contr. Cushman Lab. Foram. Res., vol. 19, pt. 3, p. 60, pl. 10, fig. 23, (synonymy); CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 84, pl. 31, fig. 1–6.

Neoflabellina reticulata (Reuss) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 97, pl. 12, fig. 13,14.

Test very thin and flattened; outline variable, rhomboidal to cordate; sides flat; early part of test coiled for about six chambers, later chambers chevron-shaped; sutures slightly raised as is the fine pattern of surface meshes at right-angles to them; aperture radiate.

Range and distribution.—*N. reticulata, s.s.*, appears to be restricted to the Maestrichtian (*Belmnitella lanceolata* zone and above) of N.W. Germany. It is also used as a zone fossil in numerous other countries, defining the lower Velasco of Mexico and upper Navarro of Texas.

Hypotype.—Queen's University, Belfast, B.C. 4-2.

NEOFLABELLINA RUGOSA (d'Orbigny)

Pl. 31, fig. 8–11

Flabellina rugosa D'ORBIGNY, 1840, Mem. Soc. Geol. Fr., Ser. 1, vol. 4, p. 23, pl. 2, figs. 4,5,7; BARTENSTEIN, 1948, Senckenbergiana, vol. 28, pt. 4–6, p. 124.

Flabellina interpunctata V.D. MARCK, 1858, Nat. Ver. Preuss. Rheinld. Westfal., (Bonn), vol. 15, p. 53, pl. 1, fig. 5.

Frondicularia baudouiniana d'Orbigny CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 21, pl. 3, fig. 5.

Palmula rugosa (d'Orbigny) SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 48–50, pl. 3, fig. 4, (synonymy).

Neoflabellina rugosa (d'Orbigny) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 97, pl. 12, fig. 15, 16.

Test thin and flattened; outline rhomboid; sides flat; early chambers coiled, later chevron-shaped, with a distinct loop at the apex; sutures raised, surface ornament consisting of many small raised granules; aperture distinct, radiate.

Range and distribution.—It would appear that this species is not known from above the *Belmnitella mucronata* zone of the upper Campanian, where it is used as an index in Europe. It is also recorded from the lower Velasco of Mexico, and from the Taylor and Navarro of Texas.

Hypotype.—Queen's University, Belfast. B.C. 9-13.

Genus FRONDICULARIA Defrance, 1824

FRONDICULARIA ARCHIACIANA d'Orbigny, 1840

Pl. 31, fig. 18

Frondicularia archiaciana D'ORBIGNY, 1840, Mem. Soc. Geol. Fr., Ser. 1, vol. 4, p. 20, pl. 1, fig. 34–36; CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 91, pl. 37, fig. 8–20, (synonymy). BANDY, 1951, Jour. Paleont., vol. 25, p. 496, pl. 72, fig. 7a,b.

Pseudofrondicularia archiaciana (d'Orbigny) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 99, pl. 13, fig. 6–8.

Test compressed, elongate, tapering slowly, maximum width at last-formed chamber; sides flattened or very slightly concave;

sutures distinct, raised, sigmoid; proloculum round and inflated, with several longtitudinal costae, which may also be slightly developed on later sutures; aperture radiate.

Range and distribution.—Although a long range form, the species is very widely distributed in the upper Senonian all over the world.

Hypotype.—Queen's University, Belfast, B.C. 4-3.

Genus PALMULA Lea, 1833
PALMULA ROBUSTA Brotzen, 1948
Pl. 31, fig. 24, 25

Test large, variable, oval in outline, flattened; sides flattened; sutures thick, distinct; initial part of test with a simple spiral, later chambers chevron-shaped; proloculum globular, inflated with two or three raised ribs.

Range and distribution.—The species is from the Maestrichtian on the continent, and occurs in the Danian of Scandinavia. It seems to be the highest index form recorded from Northern Ireland.

Hypotype.—Sedgwick Museum, Cambridge, 779-6 & 14.

Genus LAGENA Walker & Boys, 1784
LAGENA cf. L. CAYEUXI Marie
Pl. 31, fig. 22

Test spherical with remnants of a small pyramydal boss which carries the circular aperture; wall calcareous ornamented with longtitudinal striae, about six or seven visible laterally, extending from the boss to the opposite end of the test, where they interlock forming a tiny spine, [cf. *Lagena multistriata* (Marsson) 1878.]

Range and distribution.—Recorded from the Campanian, *Belmnitella mucronata* chalk of the Paris Basin, by Marie.

Hypotype.—Author's Collection, B.C. 50.

Family HETEROHELICIDAE
Genus BOLIVINOIDES Cushman, 1927
BOLIVINOIDES DECORATUS (Jones) var. DECORATUS (Jones)
Pl. 32, fig. 10–15

Bolivina decorata JONES, 1886, in Wright, Belfast Nat. Field Club Proc., N.S., App. 9, p. 330, pl. 27, fig. 7,8.
Bolivinoides decorata (Jones) CUSHMAN, 1927, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 89, pl. 12, fig. 9; ——, [part] 1946, U. S. Geol. Sur., Prof. Paper 206, p. 113, pl. 48, fig. 8,9, (synonymy, exclusive of *B. latticea*).
Bolivinoides decorata (Jones) *decorata* HILTERMANN & KOCH, 1950, Geol. Jahrb., Bd. 64, p. 606, pl. 5, fig. 3.
Bolivinoides decoratus (Jones) *var. decoratus* (Jones) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 111, pl. 16, fig. 17a,b.
Bolivinoides decorata (Jones) *var. decorata* HILTERMANN & KOCH, 1955, Geol. Jahrb., Bd. 70, p. 365, pl. 28, fig. 4.

Test rhomboid, compressed; earliest stages planispiral later biserial; chambers rather obscured by oblique ornamentation of irregular broken costae at right-angles to the sutures; aperture small, rounded, at inner margin of chamber.

Range and distribution.—Hiltermann & Koch, 1950, have clarified the northwestern European ranges of the various species and variants of *Bolivinoides*, which are distributed widely in the Upper Cretaceous throughout the world, *e.g.* in Israel, Australia and the U.S. *B. decoratus decoratus* is restricted to the highest part of the Campanian in Europe.

Hypotype.—Queen's University, Belfast, B.C. 9-9.

Genus GÜMBELINA Egger, 1899
GÜMBELINA GLOBULOSA (Ehrenberg)
Pl. 32, fig. 18

Textularia globulosa EHRENBERG, 1840, König. Preuss. Akad. Wissen. Abh., (Berlin), Jg. 1838, p. 135, pl. 4, fig. 4.
Textularia globifera REUSS [part], 1860, Kaiser. Akad. Wissen. Naturwiss. Sitz., (Wien), vol. 40, p. 232, pl. 13, fig. 7,8, (not synonymy).
Gümbelina globulosa (Ehrenberg) EGGER, 1899, König. Bayer. Akad. Wissen. Abh., (Munich), Cl. 2, vol. 21, pt. 1, p. 32, fig. 43. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 105, 106, pl. 45, fig. 9–15, (synonymy).
Gümbelina globifera (Reuss) EGGER, 1899, König. Bayer. Akad. Wissen. Abh., (Munich), Cl. 2, vol. 21, pt. 1, p. 32, pl. 14, fig. 35,36,53–55.
Gümbelina pupa (Reuss) WHITE, 1929, Jour. Paleont., vol. 3, pt. 1, p. 38, pl. 4, fig. 11, (non *T. pupa* Reuss).
Gümbelina globulosa (Ehrenberg) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 109, pl. 15, fig. 24–27.

Test tapering rapidly, broadest across last two chambers; chambers inflated, spherical, increasing in size more rapidly towards apertural end; sutures distinct, depressed; wall smooth, finely perforate; aperture broad, arched, at inner margin of last chamber.

Range and distribution.—The species is recorded from the Cretaceous of Gravesend and Paris by Ehrenberg. Cushman quotes it

as occurring mainly in the Senonian and Maestrichtian of Europe and from top Navarro to mid-Taylor in the U. S. Williams Mitchell plots its range from basal Turonian to upper Senonian with a peak in the Campanian.

A development of very small specimens only (less than 0.1 mm.), may be likely to indicate Turonian/lower Senonian, and this situation in fact exists in the Glauconitic Sands of Northern Ireland.

Hypotype.—Queen's University, Belfast, B.C. 9-14.

Genus BOLIVINITELLA Marie, 1941
BOLIVINITELLA ELEYI (Cushman)

Textularia obseleta Reuss ELEY, 1859, Geology in the Garden, p. 195–202, pl. 2, fig. 11, pl. 8, fig. 11, (non Reuss).
Bolivinita eleyi CUSHMAN, 1927, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 91, pl. 12, fig. 11; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 114, pl. 48, fig. 18–20, (synonymy).
Bolivinitella eleyi (Cushman) SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 72,73, pl. 6, fig. 10 (synonymy); FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 112, pl. 16, fig. 23.

Test very small, length/breadth 3.1, surfaces flattened or rather concave, peripheries slightly keeled; sutures rather indistinct; chambers biserial.

The species is rather rare in Northern Ireland; it occurs in the Glauconitic Sands of Keady Hill (Loc. 35) and in the Upper Chalk sample British Museum of Natural History P.41915 from Belfast. Its distinct quadrate test is rather similar in appearance to the much larger "*Textularia quadrilatera* Schw." of Chapman from Taplow.

Range and distribution.—B. eleyi occurs commonly in the Senonian of France, Arkansas, Texas, etc. Williams Mitchell plots its range from *Micraster coranguinum* to *Belmnitella mucronata* zone.

Hypotype.—British Museum of Natural History, P.41915.

Genus EOUVIGERINA Cushman, 1926
EOUVIGERINA CRETACEA Heron-Allen & Earland
Pl. 32, fig. 20

Eouvigerina americana CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 4, pl. 1, fig. 1; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 115, pl. 49, fig. 4,5, (synonymy).
Eouvigerina cretacea (Heron-Allen & Earland) WHITE, 1929, Jour. Paleont., vol. 3, pt. 1, p. 42, pl. 4, fig. 18, (not *Sagrina cretacea* Heron-Allen & Earland).
Eouvigerina americana Cushman FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 112, pl. 16, fig. 15.

Test very small, flattened laterally, giving the test a rather quadrate appearance; early chambers coiled, later biserial, of very distinct plano-convex appearance; the last chamber bears a small but distinct neck carrying the aperture, which is circular; wall calcareous, perforate.

Range and distribution.—Common in the Upper Cretaceous of Europe, and in the Taylor and Austin groups in U.S.A.

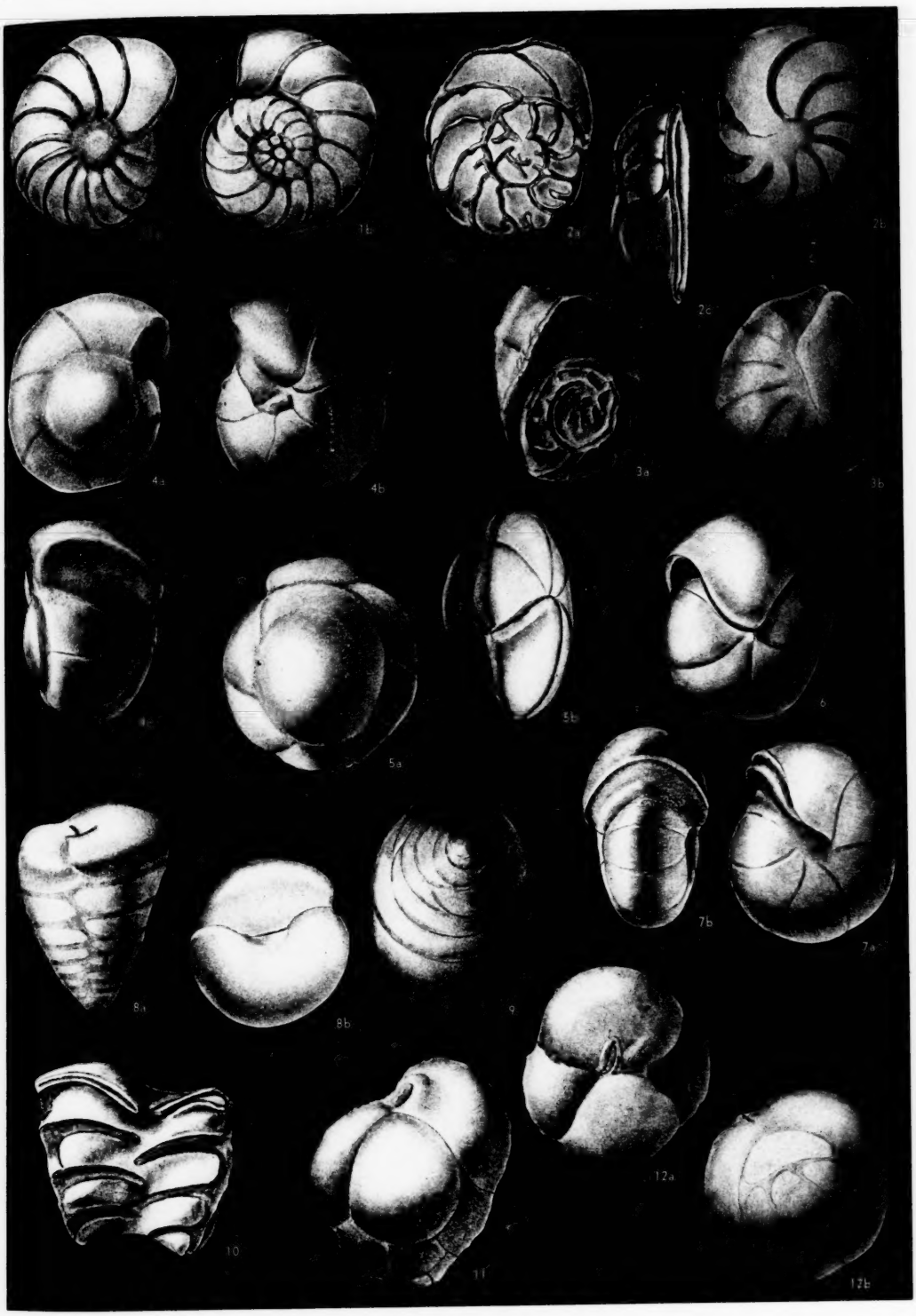
Hypotype.—Author's Collection, B.C. 38.

Family BULIMINIDAE
Genus BOLIVINA d'Orbigny, 1839
BOLIVINA INCRASSATA Reuss
Pl. 32, figs. 1–4

?Textularia elongata VON HAGENOW, 1842, Neu. Jarb. Min. etc., Stutt., p. 570 [*non* Cornuel 1848, Jones 1850, d'Orbigny 1852, Ehrenberg 1843, Hantken 1875].
Bolivina incrassata REUSS, 1851, Haidinger's Nat. Abh., vol. 4, p. 29, pl. 4, fig. 13. CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 127, pl. 53, fig. 8–11, (synonymy).

EXPLANATION OF PLATE 33

FIG. *1—Anomalina pertusa* (Marsson). B.C.5-20, ×88½.
2—Stensioina cf. *S. pommerana* Brotzen. B.C.5-3, ×78½.
3—Stensioina exsculpta (Reuss). B.C.5-4, ×84½.
4—Gyroidina umbilicata d'Orbigny. B.C.5-11, ×66½.
5—Eponides beisseli Schijfsma. B.C.5-10, ×66½.
6,7—Pullenia jarvisi Cushman. *6*, B.C.SM-16, ×56; *7*, B.C.6-9, ×86.
8–10—Marssonella oxycona Reuss. *8*, B.C.4-33, ×51½; *9*, B.C.9-11, ×69½; *10*, longitudinal section, B.C.SM-30, ×53.
11,12—Atoxophragmium subsphaerica (Marie). *11*, B.C.A-7, ×57½; *12*, B.C.4-30, ×63½.



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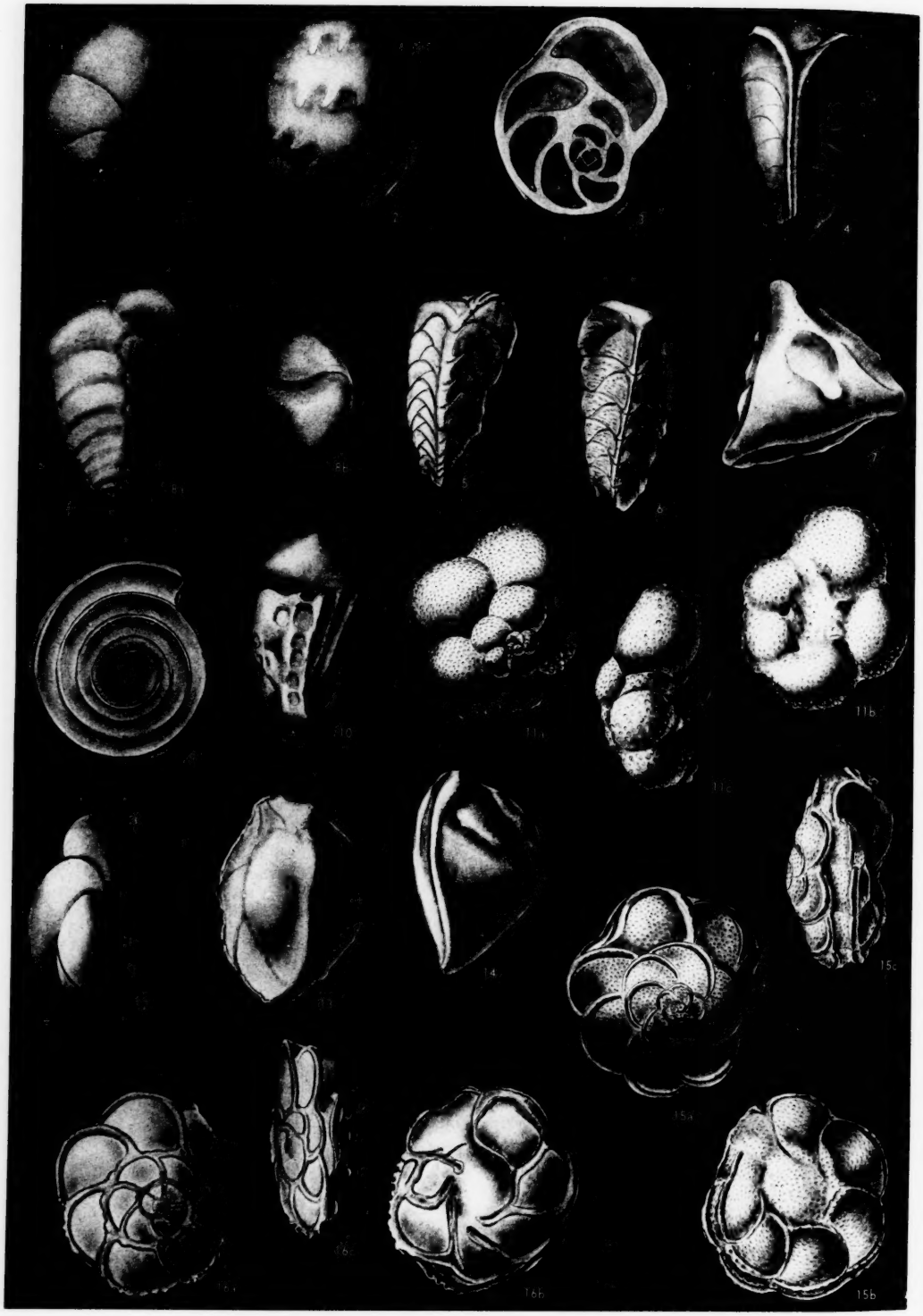

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Bolivina incrassata Reuss var. *lata* EGGER, 1899, König. Bayer. Akad. Wissen. Abh., (Munich), Cl. 2, vol. 21, pt. 1, p. 46, pl. 16, fig. 8,9.
Bolivina primatumida WHITE, 1929, Jour. Paleont., vol. 13, p. 44, pl. 4, fig. 20.
Bolivina incrassata Reuss SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 77, 78, pl. 6, fig. 9.
"*Bolivina incrassata* Reuss" FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 117, pl. 17, fig. 25.

Test elongate, slightly compressed, sometimes with a slight twist in initial end; chambers biserial; wall calcareous perforate; aperture loop-shaped, oblique, almost terminal, elongate; often the characteristic toothplate cannot be seen.

Range and distribution.—The species *sensu lato* ranges from mid-Campanian to upper Maestrichtian, but it seems likely that variants can be used for more precise zoning.

Hypotype.—Queen's University, Belfast, B.C. 4-23.

Genus BULIMINELLA Cushman, 1911
BULIMINELLA OBTUSA (d'Orbigny)
Pl. 32, figs. 5–8

Buliminella obtusa (d'Orbigny) SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 80, 81, pl. 4, fig. 9, (synonymy).

Test ovate, variable in shape, chambers arranged in an elongate spiral, about four per whorl, with about four whorls represented; not noticeably inflated; sutures distinct, not depressed; wall calcareous perforate, smooth; aperture loop-shaped, twisted, occupying a depression in the apertural face.

Range and distribution.—The species seems to have been described only from the European Upper Cretaceous, but is probably closely related to *B. carseyi* Plummer from the western hemisphere.

Hypotype.—Queen's University, Belfast, B.C. 9-10.

Family ELLIPSOIDINIDAE
Genus PLEUROSTOMELLA Reuss, 1860
PLEUROSTOMELLA SUBNODOSA Reuss

Pleurostomella subnodosa REUSS, 1860, Kaiser. Akad. Wissen. Naturwiss. Sitz., (Wien), vol. 40, p. 204, pl. 8, fig. 2; CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 132, pl. 55, fig. 1–9, (synonymy).

Test elongate, broadest across final chamber; early portion biserial, later irregularly uniserial; chambers distinct, slightly inflated; sutures distinct, slightly depressed, becoming less oblique in later part of test; aperture lateral, with lip and tooth, in flat recessed area.

Range and distribution.—The type specimen is from the Westphalian Cretaceous. The species also occurs in the U. S. in the Taylor marl, Annona chalk, etc., and in the Mendez shale of Mexico.

Hypotype.—Author's Collection, B.C. 80.

Family ROTALIIDAE
Genus STENSIOINA Brotzen, 1936
STENSIOINA EXSCULPTA (Reuss)
Pl. 33, fig. 3

Stensioina exsculpta Reuss, BROTZEN, 1936. Sver. Geol. Unders. Afh. Ser. C. No. 396. Ars. 30, No. 3, p. 165, pl. 11, fig. 8a–8c; CUSHMAN & DORSEY, 1940. Contr. Cush. Lab. Foram. Res. vol. 16, pt. 1, p. 2, pl. 1, fig. 1–3.

Test small to medium size, trochoid, biconvex, the dorsal side only slightly convex, ventral side strongly convex; ten to eleven chambers in last whorl; dorsal sutures raised, distinct, irregular; ventral sutures curved; wall perforate; aperture elongate, arched, at base of final chamber on the ventral side.

Range and distribution.—Williams Mitchell records *S. exsculpta* as a zone form in England from the top of the *Micraster corte-*

EXPLANATION OF PLATE 34

FIG. *1–3—Orbignyna ovata* v. Hagenow. *1*, B.C.5-24, ×42; *2*, stripped specimen. B.C.9-5, ×45; *3*, section, B.C.A.-13, ×42.
4–7—Verneuilina limbata Cushman. *4*, B.C.SM-32, ×45; *5*, B.C.4-37, ×28½; *6*, B.C.SM-31, ×28½; *7*, B.C.9-12, ×52½.
8—Spiroplectammina laevis (Roemer) var. *cretosa* Cushman. B.C.5-1, ×61½.
9—Ammodiscus cretaceus (Reuss). B.C.5-34, ×57.
10—Siphogaudryina cf. *S. foveolata* (Marsson). B.C.4-39, ×47.
11—Globigerina cretacea d'Orbigny. B.C.6-4, ×65.
12—Guttulina communis (d'Orbigny). B.C.6-10, ×61½.
13,14—Globorotalites conicus (Carsey). *13*, B.C.5-8, ×69½; *14*, B.C.9-22, ×69½.
15—Globotruncana arca Cushman. B.C.6-8, ×70½.
16—Globotruncana sp. [between *G. arca* and *G. ventricosa* Brotzen]. B.C.5-38, ×90.

studinarium zone to the top of the *Belmnitella mucronata* zone. Brotzen, 1936, plots its range from mid-Turonian to upper "Quadrata zone," while Hiltermann, 1952, records the range of the species from Coniacian to highest Campanian and sporadically in the lowest Maestrichtian.

Hypotype.—Queen's University, Belfast, B.C. 5-4.

STENSIOINA cf. S. POMMERANA Brotzen
Pl. 33, fig. 2
(*See* Brotzen 1936, Cushman & Dorsey, 1940)

Distinguished from *S. exsculpta* by its smaller size, flattened dorsal side, and more complex dorsal ornamentation, this species is, according to Brotzen, restricted to the "Mucronatensenon." Hiltermann, 1952, plots its range in the upper Campanian and lowest Maestrichtian, somewhat a higher index than *S. exsculpta*. Although North Irish collections contain *S. pommerana* and rare *S. exsculpta*, there also occur a large number of forms similar to *S. pommerana* which according to Brotzen (written communication) are neither *S. pommerana* nor *S. exsculpta*, although they are clearly related forms, and Hiltermann (written communication) would include some of them between *S. pommerana* and *S. exsculpta*. These will be treated for the meantime under the heading *S.* cf. *S. pommerana*.

Specimens of this group are to be found in Queen's University, Belfast, B.C. 5-3.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA UMBILICATA d'Orbigny
Pl. 33, fig. 4

?Rotalina (*Rotalina*) *umbilicata* d'ORBIGNY, 1840, Mem. Soc. Geol. Fr., vol. 4, pt. 1, pl. 3, fig. 4–6.
Gyroidina umbilicata (d'Orbigny) CUSHMAN, 1931, Contr. Cushman Lab. Foram. Res., vol. 7, p. 43, pl. 6, fig. 3.
Valvulineria cf. umbilicata (d'Orbigny) CUSHMAN, 1931, Dept. Ed. Tennessee Bull., vol. 41, p. 53, pl. 9, fig. 2–5; —— [part], 1946, U. S. Geol. Surv., Prof. Paper 206, p. 139, pl. 57, fig. 10–12 [not fig. 9], fig. 11c,12c transposed; synonymy.
Valvulineria sp. cf. *Valvulineria umbilicata* (d'Orbigny) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 123, pl. 18, fig. 38, 39.

Test trochoid, ventral side strongly convex; spiral suture slightly depressed, covered in the center by a calcareous boss; wall calcareous perforate; aperture a low slit ventrally along the inner margin of the apertural face.

Range and distribution.—Recorded from the Craie blanche of the Paris Basin, and from the Upper Cretaceous elsewhere.

Hypotype.—Queen's University, Belfast, B.C. 5-11.

Family CHILOSTOMELLIDAE
Genus PULLENIA Parker & Jones, 1862
PULLENIA JARVISI Cushman
Pl. 33, fig. 6,7

Pullenia jarvisi CUSHMAN, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 147, pl. 60, fig. 15, (synonymy).

Test planispiral, involute; periphery lobulate in side view; chambers distinct, slightly inflated, five in final coil; sutures depressed, curved; wall smooth, perforate; convex apertural face with elongate low aperture and characteristic lip.

Range and distribution.—The type specimen is from the Upper Cretaceous of Trinidad; the species is common throughout America and Europe. Williams Mitchell plots it as restricted to the *Belmnitella mucronata* and *Ostrea lunata* zones, and quotes its occurrence in the *Actinocamax quadratus* zone in Sweden. Schijfsma plots it as Campanian and Maestrichtian.

Hypotype.—Queen's University Belfast, B.C. 6-9.

PULLENIA CRETACEA Cushman

Pullenia quaternaria (Reuss) CUSHMAN, 1931, Dept. Ed. Tennessee Bull., vol. 41, p. 57, pl. 10, fig. 5 [non *Nonionina quaternaria* Reuss].
Pullenia cretacea CUSHMAN, 1936, Contr. Cushman Lab. Foram. Res., vol. 12, pt. 4, p. 75, pl. 13, fig. 8; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 146,147, pl. 60, fig. 9, (synonymy).
Pullenia coryelli White LOTTERLE, 1937, Nebraska Geol. Sur. Bull., Ser. 2, vol. 12, p. 63, pl. 11, fig. 3. CUSHMAN & TODD [part], 1943, Contr. Cushman Lab. Foram. Res., vol. 19, pt. 1, p. 6, (non White).
Pullenia cretacea Cushman SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 91, pl. 5, fig. 9, (synonymy).
Pullenia cretacea Cushman FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 126, pl. 19, fig. 19.

Test planispiral, subglobular, involute, slightly compressed laterally; periphery broadly rounded; chambers distinct, little inflated, five in final coil; sutures distinct, slightly curved; wall smooth, perforate;

aperture distinct, elongate and narrow at the base of the apertural face, with a very slight lip.

Range and distribution.—This species has a similar range to *P. jarvisi*, according to Williams Mitchell. The type is from the Upper Cretaceous of the U.S. and Schijfsma records the species from the Santonian and Campanian of Limburg.

Hypotype.—Author's Collection, B.C. 77.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA CRETACEA d'Orbigny
Pl. 34, fig. 11

Globigerina cretacea d'ORBIGNY, 1840, Mem. Soc. Geol. Fr., Ser. 1, vol. 4, p. 34, pl. 3, fig. 12–14. MARIE, 1941, Mem. Mus. Hist. Nat., N.S., vol. 12, pt. 1, p. 234. SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 93, 94.

Test trochoid, variable in shape, dorsal side convex, ventral side with open umbilicus; all chambers visible on dorsal side; ventrally only those of the last whorl which average five in number; sutures depressed; wall calcareous, perforate, with tiny spines; aperture crescent-shaped, large, opening into the umbilicus.

Range and distribution.—The species *sensu lato* ranges from upper Coniacian to lower Maestrichtian, all over the world.

Hypotype.—Queen's University, Belfast, B.C. 6-4.

Genus GLOBIGERINELLA Cushman, 1927
GLOBIGERINELLA ASPERA (Ehrenberg)

Globigerinella aspera (Ehrenberg) SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 94,95, pl. 6, fig. 8, (synonymy); BANDY, 1951, Jour. Paleont., vol. 25, No. 4, p. 508,509, pl. 75, fig. 3, (synonymy); KALININ, 1937, N. A. Lab. Pal. Univ. Mos. Stud. Micro., Moscow, vol. 1, Fasc. 2, p. 52,60, pl. 6, fig. 97–99.

Test small, planispiral, evolute; chambers globular about six in the final whorl, gradually increasing in size as added; sutures depressed; wall calcareous perforate, sometimes carrying tiny spines; aperture an arched slit at the base of the final chamber, with a small lip.

Range and distribution.—The species is recorded from the Upper Cretaceous of Germany, Holland, France, Sweden and America.

Hypotype.—Author's Collection, B.C. 81.

Family GLOBOROTALIIDAE
Genus GLOBOROTALITES Brotzen, 1942
GLOBORATALITES CONICUS (Carsey)
Pl. 34, fig. 13

Truncatulina refulgens (Montfort) *var. conica* CARSEY, 1926, Univ. Texas Bull., vol. 2612, p. 46, pl. 4, fig. 15.

Globorotalia micheliniana (d'Orbigny) CUSHMAN, 1931, Contr. Cushman Lab. Foram. Res., vol. 7, p. 45, pl. 6, fig. 8a,b,c; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 152, pl. 63, figs. 2,3, (synonymy; non *Rotalina micheliniana* d'Orbigny).

Eponides micheliniana (d'Orbigny) PLUMMER, 1931, Univ. Texas Bull., vol. 3101, p. 192, pl. 14, fig. 11, (non d'Orbigny).

Gyroidina micheliniana (d'Orbigny) CUSHMAN, 1932, Jour. Paleont., vol. 6, p. 342, pl. 51, fig. 12, (non d'Orbigny).

Gyroidina alabamensis SANDRIDGE, 1932, Jour. Paleont., vol. 6, p. 283, pl. 43, fig. 13–15.

Globorotalites micheliniana (d'Orbigny) CUSHMAN, 1948, Foraminifera, etc., ed. 4, p. 295, key plate 35, fig. 13; TEN DAM & MAGEN, 1948 [part], Rev. Inst. Fr. Petr., vol. 3, pt. 8, p. 223–224, (non fig. 8a,b,c). (Non d'Orbigny).

Globorotalites alabamensis (Sandidge) TEN DAM & MAGNE, 1948, Rev. Inst. Fr. Petr., vol. 3, pt. 8, p. 222, 223, fig. 9.

Globorotalites conicus (Carsey) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 130, pl. 20, fig. 31, (synonymy).

Test plano convex, dorsal side flat or slightly concave; ventral conical; periphery sharp, very slightly lobulate; chambers distinct, about six in final whorl; sutures distinct, not depressed, oblique on dorsal side; wall smooth; aperture elongate at dorsal margin of last chamber.

Range and distribution.—Campanian. Apparently not known from the Maestrichtian.

Hypotype.—Queen's University, Belfast, B.C. 5-8.

Family ANOMALINIDAE
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA PSEUDOEXCOLATA Kalinin
Pl. 32, fig. 22

Rosalina clementiana BEISSEL, 1891 [part], (non *R. clementiana* d'Orbigny, 1840), K. Preuss. Geol. Landes, Abh., N.S., Heft 3, Taf. 16, fig. 6-8.

Anomalina clementiana (d'Orbigny) DAIN, 1934, (non d'Orbigny), Trans. Geol. Oil Inst., ser. A, no. 43, p. 45, pl. 5, fig. 48.

Gyroidina prae-exsculpta KELLER, 1935, Bull. Soc. Nat. Mos. Sect. Geol., tome 13, no. 4, pl. 3, fig. 28–30.

Test involute; ventral side convex, dorsal side more or less flat or concave; chambers rather inflated; rounded on dorsal side,

flattened on ventral; sutures deeply depressed on ventral side, less so on dorsal, where they radiate tangentially from the line of growth; dorsal ornamentation in the form of irregular elevations concentrated in the center; wall calcareous, perforate; aperture loop-shaped, half way along the inside of the apertural face, and carrying a slit which extends ventrally.

Range and distribution.—The type level is Upper Cretaceous, Santonian; the species occurs in the Campanian and Maestrichtian of northern Europe. Some specimens from northern Ireland represent forms intermediate between *A. pseudoexcolata* and *A. clementiana* d'Orbigny.

Hypotype.—Queen's University, Belfast, B.C. 9-15.

Genus CIBICIDES Montfort, 1808
CIBICIDES VOLTZIANA (d'Orbigny)
Pl. 32, fig. 23

Rotalina voltziana D'ORBIGNY, 1840, Mem. Soc. Geol. Fr., Ser. 1, vol. 4, p. 31, pl. 2, fig. 32–34.
Cibicides spiropunctatus DAIN, 1934, Trans. Geol. Oil Inst., Ser. A, No. 43, p. 48, pl. 5, fig. 53 [*non* Galloway & Morrey].
Cibicides voltziana (d'Orbigny) MARIE, 1941, Mem. Mus. Hist. Nat., N.S., vol. 12, pt. 1, p. 246,247, pl. 37, fig. 345–347; SCHIJFSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 102, pl. 5, fig. 6.

Test approaching plano-convex condition; circular; dorsal side flattened or very slightly convex with prominent central boss. Ventral side convex with an umbo; chambers distinct, about ten visible on dorsal side; aperture a curved slit at the base of the final chamber, extending dorsally.

Range and distribution.—Widely described as *C. voltziana* and vars., the species ranges from highest Santonian to upper Maestrichtian in Europe. According to Hofker (verbal communication) although *C. beaumontianus* is a genuine *Cibicides*, *C. voltziana* is not, for its porous surface is restricted. Hofker would refer the latter species to the genus *Gavelinopsis.*

Hypotype.—Queen's University, Belfast, B.C. 5-13.

CIBICIDES BEAUMONTIANUS (d'Orbigny)
Pl. 32, fig. 24

Truncatulina beaumontiana D'ORBIGNY, 1840, Mem. Soc. Geol. Fr., Ser. 1, vol. 4, p. 35, pl. 3, fig. 17–19.
Cibicides involuta (Reuss) CUSHMAN, 1931, Jour. Paleont., vol. 5, p. 315, pl. 36, fig. 10, (non *Rotalina involuta* Reuss).
Cibicides beaumontiana (d'Orbigny) BROTZEN, 1936, Sver. Geol. Undersok. Afh., Ser. C, No. 396, vol. 30, pt. 3, p. 188, (var. *C. excavata*, p. 189,190).
Cibicides beaumontianus (d'Orbigny) CUSHMAN, 1940, Contr. Cushman Lab. Foram. Res., vol. 16, pt. 2, p. 39,40, pl. 7, fig. 9; ——, 1946, U. S. Geol. Surv., Prof. Paper 206, p. 160, pl. 65, fig. 12, (synonymy).
Cibicides excavata Brotzen SCHIFJSMA, 1946, Med. Geol. Sticht., Ser. C-V-No. 7, p. 100, pl. 6, fig. 7.
Cibicides beaumontianus (d'Orbigny) FRIZZELL, 1954, Bur. Econ. Geol. Texas, Rep. 22, p. 132, pl. 21, fig. 19.

Test plano convex, shape variable, dorsal side flattened, ventral convex, inflated; chambers distinct, about six in last whorl; aperture a curved slit at the base of the final chamber.

Range and distribution.—The species ranges from upper Campanian to upper Maestrichtian in northwestern Europe.

Hypotype.—Queen's University, Belfast, B.C. 5-17.

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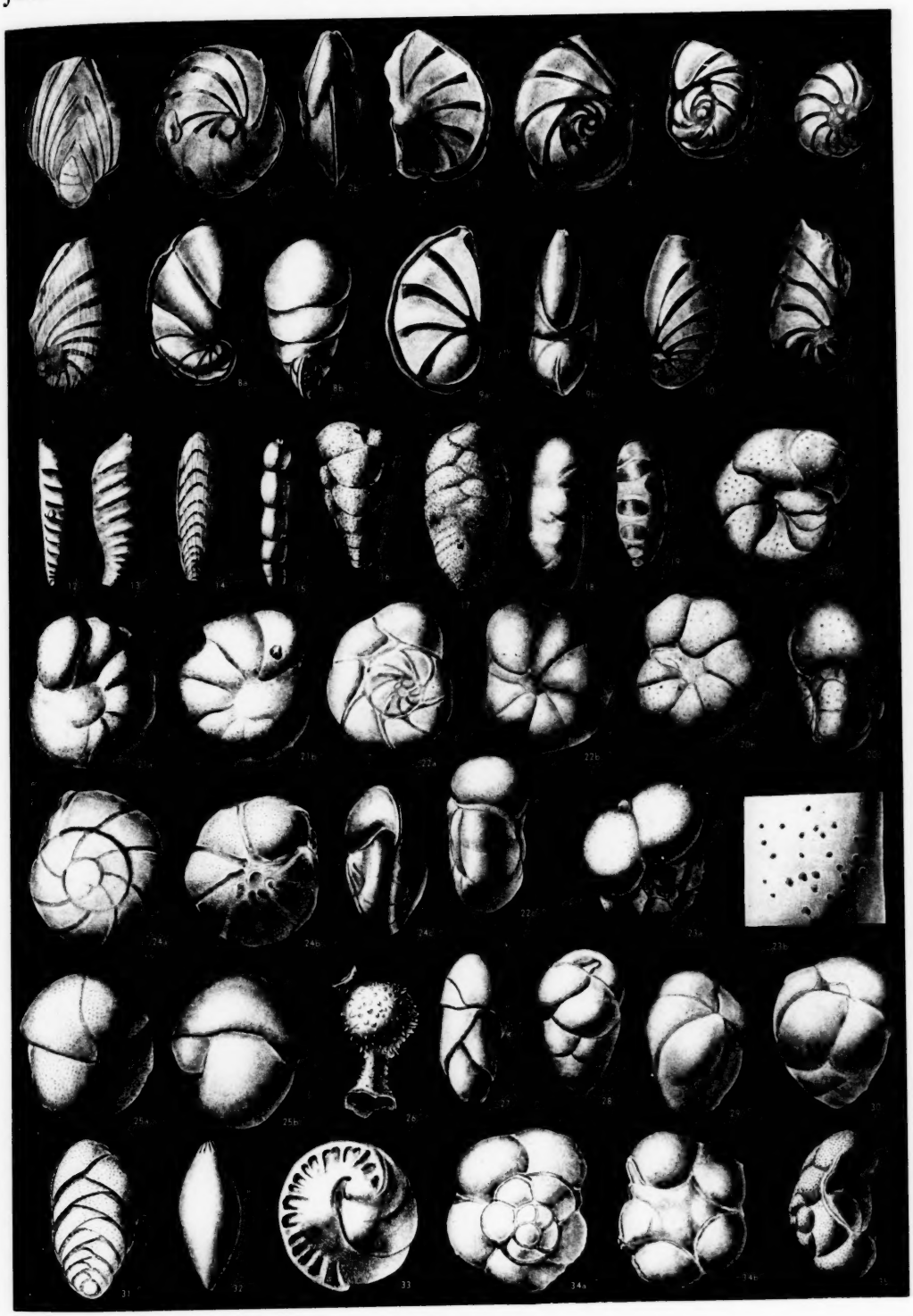
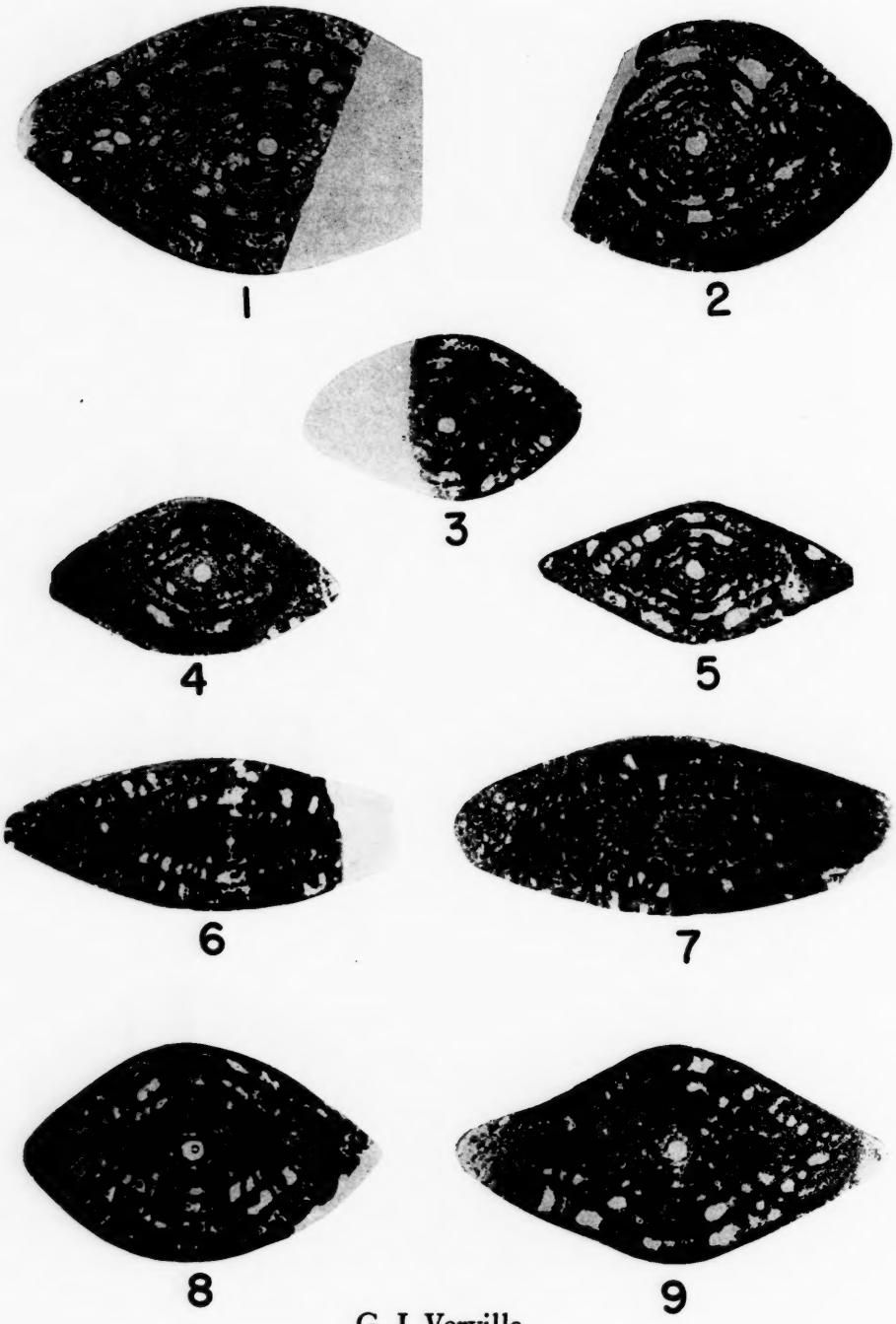
EXPLANATION OF PLATE 35

The forms illustrated are not described in the text.

FIG. *1*—*Flabellina sp.* B.C.4-2, ×19.
2–6—"*Lenticulina*" spp. B.C.4-13, ×29½; B.C.9-16, ×21; B.C.9-16, ×56; B.C.9-16, ×21; B.C.9-16, ×21.
7–11—"*Planularia*" spp. B.C.4-6, ×30; B.C.9-17, ×50; B.C.9-18, ×32½; B.C.4-16, ×36.
12,13—"*Vaginulina*" spp. SM-15, ×12½; SM-29, ×16½.
14—*Pseudofrondicularia* sp. B.C.4-5, ×23½.
15—*Nodosaria* sp. B.C.5-26, ×24.
16—*Verneuilina* sp. B.C.SM-33, ×24.
17—*Spiroplectammina* sp. B.C.5-2, ×29.
18,19—*Bulimina* sp. B.C.5-32, ×17½.
20—*Cibicides* sp. B.C.5-18, ×36.
21—*Gavelinella* cf. *G. complanata* (Reuss). C.H.SM-35, ×32½.
22—*Anomalina* aff. *A. pseudoexcolata* Kalinin. B.C.5-15, ×34.
23—*Cibicides* cf. *C. convexa*. C.H.SM-36, ×185 and ×370.
24—*Eponides* cf. *E. beisseli* Schijfsma. B.C.5-6, ×28.
25—*Pullenia* cf. *P. coryelli* White. B.C.5-22, ×59.
26—*Ramulina* sp. C.H.SM-17, ×24.
27—*Pseudopolymorphina* sp. B.C.5-28, ×34.
28–30—"*Bulimina*" spp. B.C.4-27, ×34; B.C.4-35, ×26.
31—*Bolivina* sp. B.C.6-3, ×69.
32—*Pyrulina* sp. B.C.5-36, ×29.
33—*Orbignyna* sp. C.H.SM-37, ×28.
34,35—*Globotruncana* cf. *G. marginata* (Reuss). *34*, B.C.5-37, ×67; *35*, B.C.6-4, ×102½.



Alan McGugan



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WOLFCAMPIAN FUSULINIDS FROM THE TENSLEEP SANDSTONE IN THE BIG HORN MOUNTAINS, WYOMING

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ABSTRACT—Lower Wolfcampian *Schwagerina* and *Triticites* from the upper part of the Tensleep sandstone in the Big Horn Mountains are discussed and illustrated. This fauna is the first reported occurrence of Lower Permian fusulinids in the Tensleep sandstone in Wyoming, and represents the only known occurrence of Wolfcampian fusulinids in Wyoming other than those described from the Casper formation. This fauna is correlated with similar faunas known from other parts of the country.

INTRODUCTION

THE fauna illustrated in this paper is poorly preserved and is not considered adequate for specific identifications. However, the paleogeographic significance of the occurrence of lower Wolfcampian fusulinids in the Tensleep in the southern Big Horn Mountains and its effect upon the accepted correlation of the Tensleep are of sufficient importance to warrant its publication at this time.

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HISTORICAL RESUME

The Tensleep sandstone was named by Darton (1904) from exposures in the walls of the lower canyon of Tensleep Creek, eastern Washakie County, Wyoming. At that time no fossils had been found in the Tensleep, but it was considered by Darton to represent some portion of the Upper Carboniferous.

Brainerd & Keyte (1927) identified a predominantly brachiopod fauna from the Tensleep sandstone at Sheep Mountain, north of Greybull, Wyoming. They concluded that the fossils from the Tensleep at Sheep Mountain indicated a position somewhere between the Fort Scott and the upper part of the Kansas City of the Mid-Continent Pennsylvanian section.

Branson (1939) reported *Fusulina* and *Staffella* in the Tensleep in Wind River Canyon and unidentifiable fusulinids about 115 feet below the top of the Tensleep in Tensleep Canyon. Branson considered the Tensleep fauna to be Desmoinesian in age, and probably entirely younger than Cherokee. Subsequent work has shown that *Fusulina* and *Wedekindellina* of Cherokee age are present in the Tensleep at Wind River and Tensleep canyons.

Thompson & Scott (1941) illustrated *Fusulina* and *Wedekindellina* of Cherokee age from the upper part of the Quadrant formation on Quadrant Mountain, Yellow-

EXPLANATION OF PLATE 36

Magnifications all ×10.

FIG. *1,2,8,9—Triticites* sp. A., Axial sections from the uppermost Tensleep, Big Horn Mountains, Johnson County, Wyoming.

3,4,5—Triticites sp. B., Axial sections from the uppermost Tensleep, Big Horn Mountains, Johnson County, Wyoming.

6,7—Schwagerina sp., *6*, Axial section; *7*, oblique section; both from uppermost Tensleep, Big Horn Mountains, Johnson County, Wyoming.

stone Park, Wyoming. Wanless, Bachrach, Zeller, & Johnson (1945) reported *Fusulina* and *Triticites* to be present in the Tensleep in extreme western Wyoming, and that the Tensleep in that area includes rocks of both Desmoinesian and Missourian age. Pierce (1947) reported a lower Desmoinesian fusulinid fauna from the upper part of the Tensleep at Shell Canyon. Agatston (1954) published a cross section along the western margin of the Big Horn Mountains showing Desmoinesian fusulinds to be present in the Tensleep from Tensleep Canyon to as far north as Beaver Creek. Henbest (1954) listed Desmoinesian fusulinids from the Tensleep sandstone in the northern Big Horn Mountains in Wyoming and Montana and from the Wind River Mountains in Wyoming. Wanless, Belknap, & Foster (1955) reported *Fusulinella* of Atokan or Lampasas age from the Tensleep in the Gros Ventre Range and *Triticites* of middle Missourian age from the Tensleep in the Snake River Range. It was also suggested that rocks of Virgilian age may be present in the interval above the *Triticites* horizon in the Snake River Range.

STRATIGRAPHIC CONSIDERATIONS

With the exception of the works published by Wanless *et al.* (1945, 1955), Thompson & Scott (1941), and part of Henbest (1954), all of the above fusulinid references are concerned with the Tensleep sandstone near the western and northwestern margins of the Big Horn Mountains. In this part of the Big Horn Mountains, the Tensleep sandstone is relatively thin, and the fusulinids which are Desmoinesian in age occur in the upper parts of the section.

The Tensleep sandstone in the southern Big Horn Mountains contains the lower Wolfcampian fusulinids *Schwagerina* and *Triticites*. These fusulinids were found in the uppermost part of the Tensleep sandstone along the eastern flank of the Big Horn Mountains, about four miles southwest of Mayoworth. The Desmoinesian fusulinids *Wedekindellina* and *Fusulina* are also present in the Tensleep in the southern Big Horn Mountains. Here, however, the Desmoinesian fusulinids occur from 300 to 400 feet below the top of the Tensleep.

The northward thinning of the Tensleep sandstone has been reported by several authors and is especially well shown in the cross sections published by Agatston (1954). This thinning may be due in part to a regional thinning of Tensleep deposition in a northerly direction. However, it appears that erosion at the top of the Tensleep is the principal reason for the northward thinning. In the southern Big Horn Mountains, erosion of upper Tensleep occurred after deposition of lower Wolfcampian. From the standpoint of geologic history and paleogeographic interpretation, this event apparently occurred somewhat later than has heretofore been recognized. Agatston (1954) postulated that the Big Horn region probably became emergent during the Missourian, with the intensity of upwarp increasing during the Virgil, and attaining its maximum during Lower Permian.

The occurrence of lower Wolfcampian fusulinids in the upper part of the Tensleep in the Mayoworth area of the Big Horn Mountains extends the areal distribution of known Lower Permian rocks in Wyoming. Previous correlations between the Casper and Tensleep formations have been based largely on the supposition that the Tensleep sandstone is no younger than Desmoinesian or possibly middle Missourian in age and that the Casper formation ranges in age from Desmoinesian to lower Wolfcamp. The Wolfcampian fusulinids from the Tensleep sandstone are closely similar, if not conspecific with, the Wolfcampian fusulinids described by Thompson & Thomas (1953) from the Casper formation in the Laramie Range. The Tensleep sandstone in the southern Big Horn Mountains ranges in age from Desmoinesian (Cherokee) to lower Wolfcampian and is correlative with almost all of the Casper formation exposed in the Laramie Range. The only part of the Casper formation which may be slightly younger than the Tensleep is the unfossiliferous part occurring stratigraphically above the highest occurrence of *Schwagerina* and *Triticites*. Although *Wedekindellina* has not been described from the Casper formation in the Laramie Range, the presence of *Fusulina plattensis* in the Casper formation (Thompson & Thomas, 1953) strongly suggests that rocks of Cherokee age are present in the lower part of the Casper formation. Agat-

ston (1954) states that fusulinids of middle Cherokee age occur 80 feet above the base of the Casper formation in Granite Canyon.

Rocks of pre-Desmoinesian age may be present in the lower part of the Casper formation; however, Thompson, Thomas, & Harrison (1953) suggested that since Desmoinesian fusulinids were found only a short distance above the Pre-Cambrian in the southern part of the Laramie Range that the basal beds of the Casper formation in Gilmore Canyon-Granite Canyon area are no older than Desmoinesian.

Tensleep equivalents in the Hartville Uplift in southeastern Wyoming include Divisions I, II, III, and the upper part of Division IV of the Hartville formation (Condra & Reed, 1935; Condra, Reed, & Scherer, 1940). Divisions IV and V of the Hartville formation have been considered to be Atokan in age by some authors (Love, Henbest, & Denson, 1953; Bates, 1955); however, the occurrence of *Wedekindellina* about 90 feet below the top of this unit (combined Divisions IV and V) makes it necessary to consider that at least this upper 90 feet is Desmoinesian Cherokee in age.

PALEONTOLOGIC CONSIDERATIONS

The specimens collected and studied for this paper are so poorly preserved that reliable measurements cannot be obtained. It is hoped that in the future better preserved material will become available for study.

A few generalized statements concerning the affinities of this fauna will be sufficient to establish the objectives of this paper. The lower Wolfcampian fusulinids illustrated and discussed in this paper were collected from the uppermost part of the Tensleep along the eastern flank of the Big Horn Mountains in Section 8, T. 44 N., R. 83 W., Johnson County, Wyoming.

Schwagerina and *Triticites* indicate that the upper part of the Tensleep sandstone in the southern Big Horn Mountains is Lower Permian in age. This determination is significant in view of the fact that over much of central Wyoming the Tensleep has been considered to be no younger than Middle Pennsylvanian in age. The lower Wolfcampian fauna of the upper Tensleep can be correlated with lower Wolfcampian faunas in the Mid-Continent area, north-central Texas, and the type Wolfcamp section of West Texas. The Tensleep in the southern Big Horn Mountains is to be correlated with most of the Casper formation in the Laramie Range and with Divisions I, II, and III, and the upper part of combined Divisions IV and V of the Hartville formation of southeastern Wyoming. The increased areal extent of known Wolfcampian rocks in Wyoming necessitates some reinterpretation of the paleogeography and the geologic history of the Tensleep sandstone.

TRITICITES sp. A
Pl. 36, fig. 1,2,8,9

The large specimens illustrated as *Triticites* sp. A are most closely similar to *Triticites notus* Thompson & Thomas (1953) from the Casper formation in the Laramie Range. The Tensleep specimens are slightly larger, more inflated fusiform, possess a somewhat smaller form ratio for outer volutions, and are in some cases more highly fluted. The Tensleep specimens are similar to *T. notus* in proloculus diameter, spirothecal thickness, tunnel angle, and chomata development.

Tricities sp. A is similar in many respects to *Triticites pinguis* Dunbar & Skinner from the lower part of the Wolfcamp formation, Glass Mountains, Texas.

Triticites sp. A is considered to be lower Wolfcampian in age, and that part of the Tensleep sandstone from which it was obtained is correlated with the lower Wolfcampian part of the Casper formation in the Laramie Range, the lower part of the Council Grove Group in Kansas, the Camp Creek shale of north-central Texas, and the lower part of the Wolfcamp formation in the Glass Mountains of Texas.

TRITICITES sp. B
Pl. 36, fig. 3–5

The specimens here referred to as *Triticites* sp. B are illustrated mainly for the purpose of showing the variations in the Tensleep Wolfcampian fauna. The smaller size, fewer volutions, smaller proloculus, and more sharply pointed poles serve to distinguish *Triticites* sp. B from the specimens illustrated as *Triticites* sp. A. *Triticites* sp. B appears to be similar in over-all shell development to the specimens described by

Thompson & Thomas (1953) as *Triticites* aff. *T. ventricosus* from the Casper formation.

SCHWAGERINA sp.
Pl. 36, fig. 6,7

Specimens of *Schwagerina* sp. are rare in our collections from the upper Tensleep. However, these few specimens of *Schwagerina* certainly demonstrate that the upper part of the Tensleep from which they were collected is lower Wolfcampian in age. The specimens illustrated as *Schwagerina* sp. are similar to specimens described from the upper part of the Casper formation and to others from lower Wolfcampian rocks in the Mid-Continent region and Texas.

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DEVONIAN CONODONT FAUNAS FROM SOUTHWEST ENGLAND

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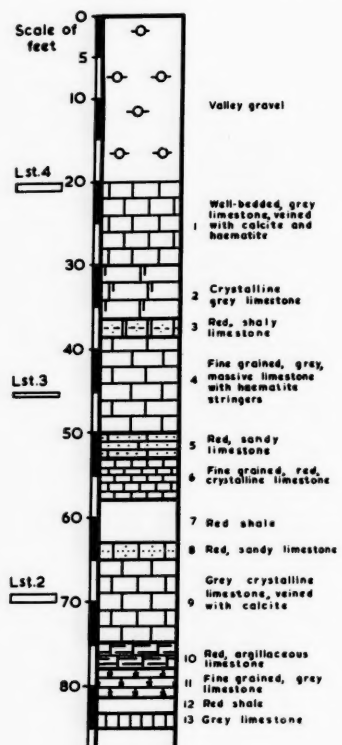
ABSTRACT—Thirteen genera of conodonts are represented in four samples of limestone from a Devonian limestone-shale sequence at Bishopsteignton, South Devon, England. The exact stratigraphic position of these samples is uncertain, but it is probable that they fall within the Frasnian and Famennian stages. *Belodus*, *Hindeodella*, *Ozarkodina*, and *Polygnathus* are the genera most abundantly represented. The "Ordovician" forms present, *Belodus* and *Paltodus*, are regarded as a stratigraphic admixture. *Hibbardella*, *Polygnathus*, *Prioniodina*, and *Synprioniodina* have not been recorded from strata older than the Upper Devonian elsewhere; *Centrognathodus* and *Elsonella* appear to be confined to that division. The supposedly Upper Devonian genera *Ancyrodella*, *Ancyrognathus*, *Icriodus*, *Palmatolepis*, and *Polylophodonta* are not present at Bishopsteignton. A new species of *Belodus* and one of *Ozarkodina* are described. The fauna is similar to those described from Cedar Valley limestones in Minnesota, where "Ordovician" forms are also associated with the Devonian. The age of that formation seems to be Middle Devonian, though an Upper Devonian age has also been suggested.

INTRODUCTION

CONODONTS from Devonian limestones near Newton Abbot, South Devon, England were recorded many years ago by Young (1880). Others have since been obtained from horizons within the British Upper Paleozoic rocks, but no serious study of them has yet been made. The writers have made a wide search for conodont-bearing horizons in the Devonian and Carboniferous rocks of South West England, and the present paper describes conodonts from limestones taken from a borehole at Bishopsteignton, near Newton Abbot. The South Devon region is structurally complex and has suffered a widespread low-grade metamorphism, rendering the selection of a suitable type section difficult. Macrofaunas, where they exist, usually are poorly preserved. The classical type localities of the Devonian of western Europe have not been systematically searched for conodont faunas, so that the British species must generally be compared with those of North America, where the Devonian conodonts are particularly well known. Certain German micropaleontologists, however, are at present investigating the conodont faunas of the Rhenish Upper Devonian (Beckmann, 1953; Sannemann, 1953, 1955). Sannemann (1955) has suggested that some form of zoning by means of conodonts may be possible in the Upper Devonian of the Frankenwald.

It has been found that in Devon the rocks most readily yielding conodonts are limestones, and the cores from the borehole described below have provided the first large faunas obtained from South Devon. The borehole is situated some 50 yards north of the Newton Abbot-Teignmouth road, between Floor Lane and Church Road in the village of Bishopsteignton on the north side of the Teign Estuary (national grid reference = 21/910733). The local geology has been described by Ussher (1913). The massive limestones here and at Newton Abbot and Chudleigh were regarded as Upper Devonian by Ussher, and Anniss (1933) established the Frasnian and Famennian age of the beds at Chudleigh, four miles away to the northwest. Lloyd, in a revision of the Geological Survey's Torquay Memoir (1933), suggested correlations of the Upper Devonian occurring south of the River Teign with the stages recognized on the continent.

The succession within the Upper Frasnian and Famennian north of Bishopsteignton is rather different from that to the south, where thick volcanics are interbedded with the sediments. The shales and limestones at Bishopsteignton are dull green, grey-blue and, less frequently, red. Bright colors are



dominant near Torquay, and calcareous material occurs not only as bedded limestone but also in the form of numerous bands of concretions and nodular marl comparable with the distinctive Knollenkalk and Krammenzelstein types of lithology. Anniss (1933) distinguished a group of variegated "Entomis" shales near Chudleigh lying above thin limestones and shales, together constituting a "Red Series" (Famennian) distinct from the "Massive (Cuboides) limestone" below. Conodonts have now been collected from both the "Massive Limestone" and the "Red Series" in the Chudleigh area and from the equivalent beds near Torquay.

THE BOREHOLE SECTION

The borehole was drilled through some 20 feet of valley gravel into the underlying Devonian limestones and shales to terminate in soft, red, micaceous shales at 170 feet below the surface. The lithologies encountered are similar in part to those at Chudleigh and in part to those at Torquay and Saltern Cove, near Paignton (Anniss, 1927). The actual succession is puzzling (Text-fig. 1). The uppermost beds are typically massive and well-bedded dark grey limestones. Red limestones appear below, and the strata become progressively more argillaceous with depth. The greater part of the lower half of the section consists of red shales within thin limestones and contains pods, veins, and partings of calcite and recrystallized nodules of the Knollenkalk and Krammenzelstein type. There is no indication of any volcanic material in the section.

Except near the base of the borehole, there is no evidence that faults cut the strata, but the limestones occasionally contain veins and partings of calcite and hematite. The strata appear to be horizontal or nearly so.

The uppermost limestones are similar to those found just above the outcropping "Massive (Cuboides) Limestone" at Chudleigh, and the thin-bedded red shales and reddened limestone in the mid-parts of the borehole appear similar in lithology to the "*Clymenia laevigata* limestone and shale" of

TEXT-FIG. *1*—Diagrammatic section of the strata penetrated by the borehole at Bishopsteignton.

Anniss at Well and Olchard. The shales near the bottom of the borehole, unlike rocks higher up, did not yield cores and were extracted in an extremely broken state. They may have been shattered by faulting or thrusting. Otherwise they are very similar to, and may be coeval with, the "Entomis" shales near Torquay.

As outlined above, the borehole section shows a general inversion of the sequence found at Chudleigh. West of Bishopsteignton the main outcrop of the massive limestone is bounded by volcanic rocks and, according to Ussher (1913), the junction is inverted. The field evidence is as yet not conclusive, but it appears possible that much of the Devonian outcropping at Bishopsteignton is inverted. If such an inversion can be demonstrated, the close similarity of the sequence here to that at Chudleigh becomes clear. The 17 feet of massive gray limestone at the top of the section may then be Lower Frasnian and the 70 feet of limestones and shales below may be Upper Frasnian and Lower Famennian in age, accepting Anniss's dating of the Chudleigh sequence as correct. The conodont faunas, however, do not confirm an Upper Devonian age for the borehole section. As discussed below, a Middle Devonian element is present, while certain supposedly charactristic American Upper Devonian forms have not been found.

EXAMINATION OF MATERIAL

Samples of limestones and shales were taken from the cores. Fifteen samples of limestone, each of about two pounds weight, taken at approximately 10-foot intervals in the upper parts of the borehole and more irregularly at lower horizons, were digested in 15 percent acetic acid, and the residues were afterwards sieved and sorted. Several samples of shale were examined under a binocular microscope but no fossils were detected. The borehole yielded no macrofauna beyond a few brachiopod fragments.

Only four samples of limestone yielded any micro-fauna. They were those taken from approximately 20, 46, 69, and 104 feet below ground level. Each sample yielded less than one ounce of residue. Besides conodonts, a few siliceous sponge spicules and small straw-colored spheres, which appear to be identical to the egg cases? recorded by Stauffer (1940, p. 434) were collected.

GENERAL REVIEW OF THE CONODONT FAUNA

The conodonts present in limestone from the borehole represent thirteen genera, of which the most common are *Belodus*, *Hindeodella*, *Polygnathus*, and *Ozarkodina*. The remainder appear to be relatively rare. The "accepted" ranges of these genera, based upon those given by Ellison (1946) and Fay (1952), with some minor modifications by Rhodes (1953a), are plotted (Text-fig. 2). Reference to this figure will reveal, that with two striking exceptions, these ranges suggest an Upper Devonian age for the present faunas. The genera *Hibbardella*, *Polygnathus*, *Prioniodina* and *Synprioniodina* have not been recorded from strata older than Upper Devonian, and *Centrognathodus* and *Elsonella* appear to be confined to the Upper Devonian.

A puzzling feature of this fauna is the apparent absence of such typical and characteristic Upper Devonian genera as *Ancyrodella*, *Ancyrognathus*, *Palmatolepis* and *Polylophodonta*. *Icriodus* is also apparently absent; however, the authors have found it together with some of the other listed genera, in other Devonian faunas from southwest England. These genera are frequently present in Upper Devonian strata of North America and Europe, although Stauffer (1940) records only *Icriodus* from the Devonian of Minnesota. The absence of such forms at Bishopsteignton may perhaps be explained by the relatively small samples available for study from the borehole, or it may be that the age of the present fauna is pre-Upper Devonian, and that the "Upper Devonian" genera which do occur in it, occur in older beds in England than they do in North America. The genera *Belodus* and *Paltodus* are regarded by most conodont students as restricted to the Lower Paleozoic.

There is a similarity between this fauna and that described by Stauffer (1939, 1940) from within and from the clays above the Cedar Valley Devonian limestones of Minnesota, although the British fauna contains a much smaller number of species than does that of Minnesota. The following forms are common to both faunas: *Belodus triangularis*

Stauffer, *B. devonicus* Stauffer, *Lonchodina* cf. *L. disjuncta* Stauffer, *Polygnathus linguiformis* Hinde, *P. varcus* Stauffer, *P. xylus* Stauffer and *Synprioniodina forsenta* Stauffer. Downs & Youngquist (1950) collected *Hindeodella, Icriodus, Ozarkodina* and *Polygnathus xylus* from the Cedar Valley Limestone in Iowa, and they referred this formation to the Middle Devonian, though an Upper Devonian age had previously been suggested more than once. Although Stauffer's faunas and those of Downs & Youngquist appear to be Middle Devonian in age, it does not necessarily follow that these species are exclusively Middle Devonian. Thomas (1949), for example, has recorded *Polygnathus linguiformis* from the Maple Mill (Upper Devonian) shale of south-eastern Iowa.

THE POSSIBILITY OF A STRATIGRAPHIC ADMIXTURE

The presence of *Belodus* and *Paltodus* in the present fauna represents a conspicuous anomaly. Most conodont students consider *Belodus* to be exclusively Ordovician in age, and *Paltodus* exclusively Ordovician and Silurian in age, since their occurrence in younger strata is largely unknown. There are, however, two striking exceptions. Bond (1947) reported distacodids from the Ohio shale (Devonian), although *Paltodus* does not appear to be represented in the three specimens figured. Stauffer (1940) recorded *Paltodus* and species of *Belodus* identical to those here recorded in the Devonian limestones and associated clays from Minnesota mentioned above. Other "distacodids" in post-Silurian deposits almost certainly represent broken fragments of large denticles of other genera. Neither Bond's nor Stauffer's nor the present specimens can, however, be interpreted in this way. The only alternative explanations are that (a) the ranges of *Belodus* and *Paltodus* extend further upwards into beds younger than those at present recognized, or (b) the present fauna represents a stratigraphic admixture, in which the Lower Paleozoic conodonts have been redeposited as detrital sediments in a Devonian sea. If such is the case, then the presence of both genera would seem to indicate that land composed of Ordovician rocks was undergoing erosion in Southern England in Devonian times. Other Lower Paleozoic genera have been found in faunas from the Pilton Beds (Upper Devonian) of North Devon.

The possibility of a longer time range than that which is generally assumed for these genera appears unlikely. A total of some one hundred Devonian conodont faunas has been studied and described, and only in the two discussed above is there an anomalous occurrence of genera.

The interpretation of the present fauna as a stratigraphic admixture appears more justifiable. Such mixtures are known in a number of instances in conodont faunas (Branson & Mehl, 1940), some ten samples having been recorded. In such cases the derived conodonts may or may not show signs of wear. In several of the examples referred to above, mixture has apparently taken place in transgressive seas, the mixed faunas being found in the basal sediments of the younger formations.

It will be noted in Table 1 that all four limestone samples yield *Belodus*, while two yield *Paltodus*. None of the core samples from which the conodonts were collected represents the basal member of any of the limestone formations. Further, the present specimens of these two genera are indistinguishable in their perfect state of preservation from the accepted indigenous Devonian forms. They show no signs of wear or erosion, and have a glossy surface texture and pale straw color similar to the indigenous forms.

Of the two possible alternatives, the authors favor stratigraphic admixture. The lack of any signs of wear and the presence of derived conodonts are, however, obvious difficulties.

A more striking coincidence is the very close similarity between Stauffer's (1940) Devonian fauna and the present faunas. The virtually identical forms present in both suggest longer ranges of genera, even though the suggestion of a stratigraphic admixture is preferred. The problem must await final solution until considerably more is known of European and American Devonian faunas.

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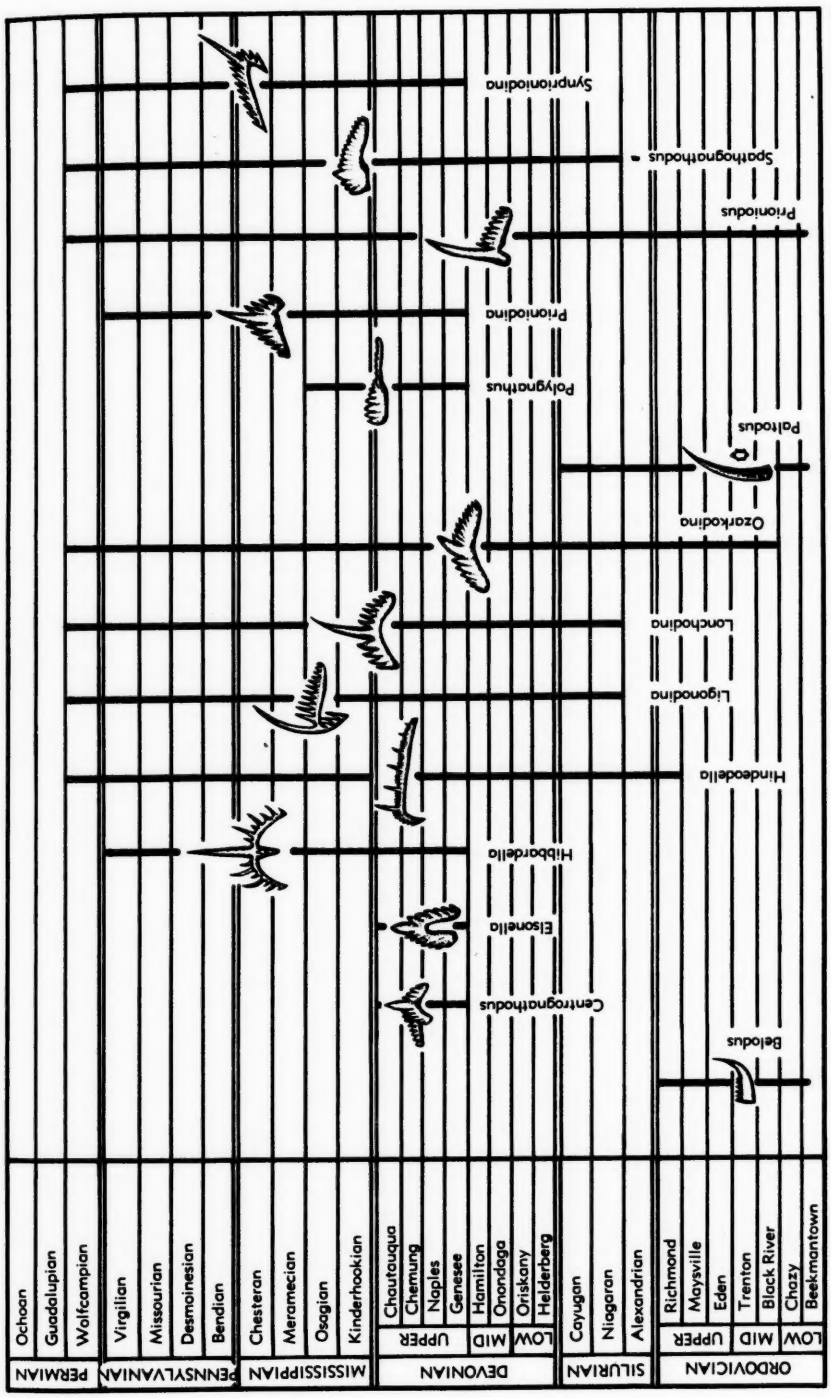


TEXT-FIG. 2—Chart showing stratigraphical ranges of the genera found at Bishopsteignton, largely after Ellison (1946) with modifications by Rhodes (1953).

TABLE 1—OCCURRENCE OF CONODONT SPECIES IN LIMESTONES OF THE BISHOPSTEIGNTON BOREHOLE

	Sample No.			
	4	3	2	1
Belodus erectus n. sp.	X			
B. triangularis Stauffer	X	X	X	X
Belodus sp.	X			
Belodus cf. *B. devonicus* Stauffer	X	X	X	X
Centrognathodus sp.	X			
Elsonella sp.	X			
Hibbardella angulata (Hinde)		X		
Hibbardella cf. *H. multidens* Ulrich and Bassler	X			
Hibbardella sp.	X			
Hindeodella spp.	X	X	X	X
Ligonodina cf. *L. flexuosa* Branson and Mehl	X			
Ligonodina sp.	X			
Lonchodina alternata Ulrich and Bassler	X	X		
Lonchodina cf. *L. disjuncta* Stauffer	X			
Lonchodina cf. *L. paucidens* Ulrich and Bassler	X			
Ozarkodina willei n. sp.	X	X		
Ozarkodina cf. *O. firma* (Stauffer)			X	
Ozarkodina cf. *O. plana* (Huddle)	X			
Ozarkodina spp.	X	X	X	X
Paltodus sp.	X		X	
Polygnathus linguiformis Hinde	X	X		
P. varcus Stauffer				X
P. xylus Stauffer	X	X	X	X
Prioniodina subcurvata Ulrich and Bassler	X			
Prioniodus cf. *P. idoneus* Stauffer				X
Spathognathodus sp.				X
Synprioniodina forsenta Stauffer	X			
Synprioniodina ? sp.		X		

for samples from the borehole and for information concerning the succession there. The thanks of one of them (F.H.T.R.) are due to the Royal Society, the Durham Colleges in the University of Durham, and the University of Illinois and of the other (D.L.D.) to the University of Exeter for research funds and facilities during the progress of the work.

SYSTEMATIC PALEONTOLOGY

The super-generic classifications of Ulrich & Bassler and of Branson & Mehl are not used in the present paper. Conodont genera are arranged alphabetically. The text-figures which accompany the descriptions are generalized drawings designed to show the more characteristic generic features. Catalogue numbers refer to slides deposited in the Geology Department of the University of Exeter, England.

Genus BELODUS Pander, 1856

Type species: *B. gracilis* Pander.

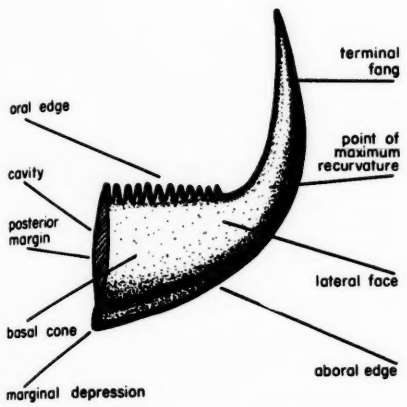
Stauffer (1935a, 1935b) gives two slightly different tranlations of Pander's generic description. Branson & Mehl (1933, p. 97) also emended the description.

BELODUS TRIANGULARIS STAUFFER
Pl. 37, fig. 1,2

Belodus triangularis STAUFFER, 1940, p. 420, pl. 59, fig. 49; FAY, 1952, p. 67.

Specimens which can be referred to this species are common in the present faunas. They exhibit the characteristic hollow cone, open at its posterior end, triangular in cross-section, with a flat base and an outer face intersecting the base at an angle of about 90°. If Branson & Mehl's terminology is used, rather than Stauffer's, the outer lateral face would include also the "base." The oral edge is surmounted by numerous, crowded, small erect denticles, which extend just beyond the point of maximum recurvature, towards which they tend to become smaller in size.

The fang is slender and pointed with its apical cross section sub-circular. No conspicuous basal flanges are developed. There



TEXT-FIG. 3—*Belodus* sp.

appears to be considerable variation in the depth of the basal cone among specimens.

Figured specimens.—Catalogue numbers 2–9, 3–26.

Occurrence.—Samples 1, 2, 3 and 4

BELODUS ERECTUS n. sp.
Pl. 38, fig. 8

A *Belodus* with long, slender fang, with inwardly off-set anterior edge. The denticles of the oral edge about ten in number, very short, unequal. The posterior margin of the cone very deep. Outer lateral face convex, inner lateral face almost flat.

Basal cone deep posteriorly, but tapering sharply towards the point of maximum recurvature; the fang slender, the lower portion continuously recurved, the apical portion straight and making an angle of about 90° with the oral edge of the basal cone. Aboral margin of basal cone conspicuously laterally compressed, giving a sharp edge and a conspicuous marginal depression on each of the lateral faces, which on the outer face decreases in width towards the point of recurvature, where it becomes inconspicuous. The oral edge tends to have a similar marginal depression below the denticles. Outer lateral face strongly convex, inner almost flat, with regular basal depression. The fang is slender, long, basally recurved, but the apical portion is straight; it is laterally twisted, so that it has an anterior inner edge; its outer-anterior face is strongly convex, its inner posterior face flatter, especially near its base. Denticles of oral edge very short, crowded but discrete; unequal, erect, strongly laterally compressed with sharp anterior and posterior edges and gently convex lateral faces; confined to portion of basal cone below point of maximum recurvature. Whole unit deeply excavated, walls very thin.

Remarks.—This species is readily distinguished from all others by the diagnosis given. It differs from *B. grandis* Stauffer and *B. wykoffensis* Stauffer in its more slender construction, its deep posterior, unflared margin, and its very small, posteriorly restricted, oral denticles.

Types.—Catalogue numer 1–4 (holotype), 3–10 (paratype).

Occurrence.—Samples 1 and 4

BELODUS sp.
Pl. 38, fig. 9

A single poorly preserved specimen has a massive basal cone, with a very conspicuous outer lateral ridge, four widely spaced oral denticles, and a slender, slightly recurved fang.

Figured specimen.—Catalogue number 2–15.

Occurrence.—Sample 4

BELODUS cf. B. DEVONICUS Stauffer
Pl. 37, fig. 3

Belodus devonicus STAUFFER, 1940, p. 420, pl. 59, fig. 47,48; STAUFFER & THIEL, 1941, p. 229; FAY, 1952, p. 67.

A number of the present specimens are closely comparable with Stauffer's figured holotype of this species. There appears to be a slight variation in the present specimens in the size of the terminal cusp and considerable variation in the depth of the basal cone.

Remarks.—Some specimens show considerable lateral curvature of the anterior end, so that one lateral face is conspicuously concave and the other convex.

Figured specimen.—Catalogue number 3–9.

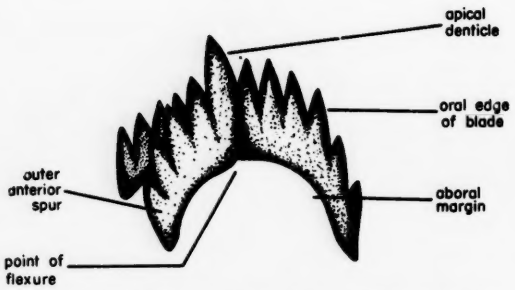
Occurrence.—Samples 1, 2, 3 and 4

Genus CENTROGNATHODUS (CENTROGNATHUS) Branson & Mehl, 1933

Type species: *C. sinuosa* Branson and Mehl.

CENTROGNATHODUS sp.
Pl. 37, fig. 4

A fragmentary specimen appears to belong to this genus. The blade is strongly



TEXT-FIG. 4—*Centrognathodus* sp. Outer lateral view. Terminology of a broken specimen.

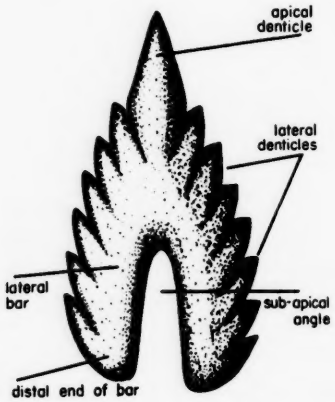
arched in a vertical plane, deep and strongly compressed laterally; very feebly out-flexed in a horizontal plane, with the anterior end in-flexed and down-flexed; an outer-anterior spur is developed just posterior to the point of flexure of the anterior bar. The oral edge of the blade is crowned with a series of sub-parallel, posteriorly inclined denticles, which are discrete, except at their bases, sub-circular in cross-section, and which tend to decrease in size towards the distal ends of the bar. The denticles are inclined sub-parallel to the plane of the outer-anterior spur, there being at least four or five on each side of its point of origin, which is marked by the development of the largest denticle; the length of any one of these denticles is approximately equal to the depth of the bar below it, which also decreases towards the distal ends of the bar. The outer-anterior spur is biconvex in cross-section; it is broken in the present specimen and no oral denticles can be observed. The aboral edge of the unit is regularly concave below the apex, the lateral faces of the bar feebly convex, and the aboral margin blade-like.

Figured specimen.—Catalogue number 2-3.

Occurrence.—Sample 4

Genus ELSONELLA Youngquist, 1945
Type species: *E. prima* Youngquist.

Ellison (1946, p. 108) has suggested that this genus represents a junior synonym of

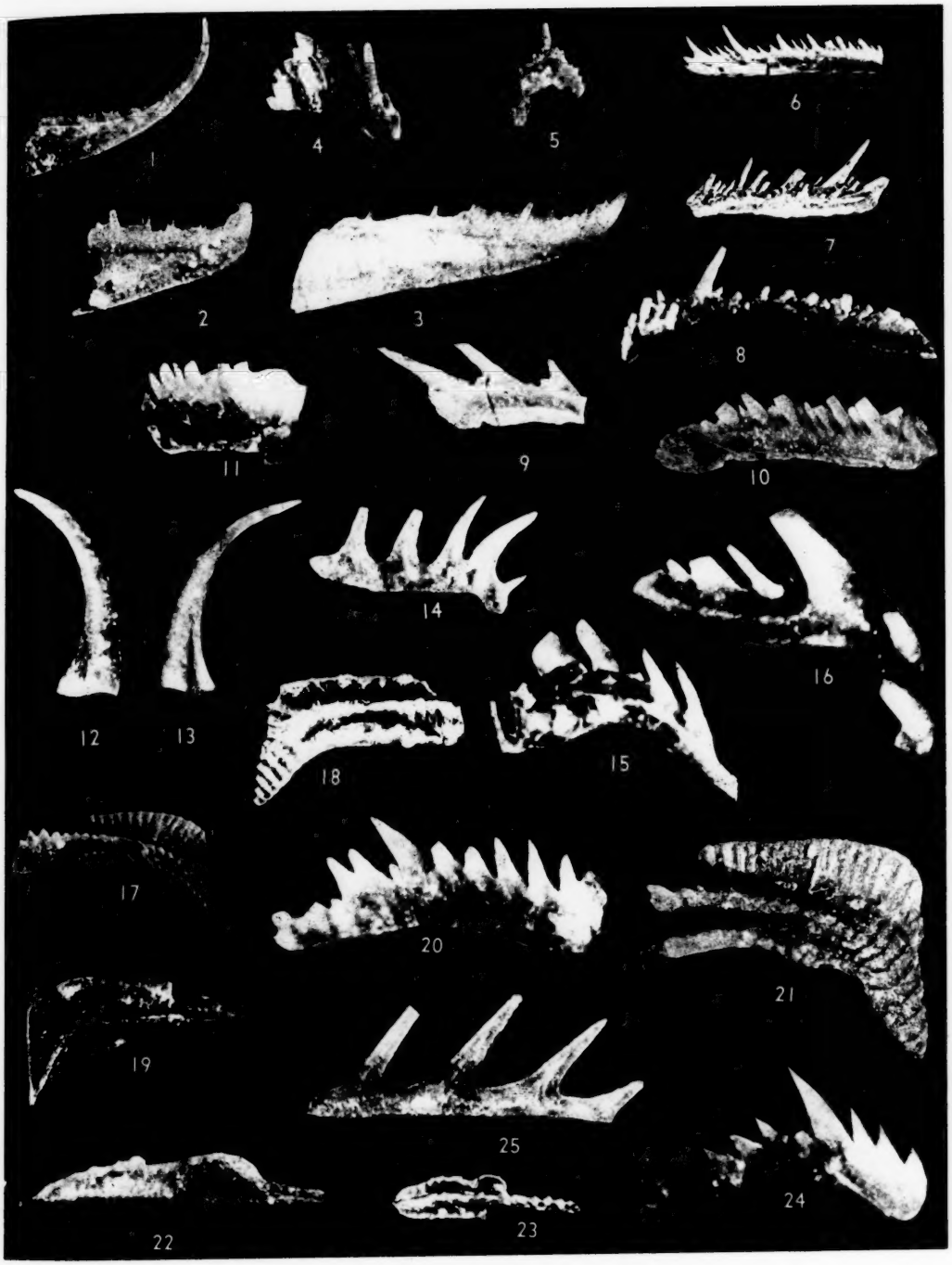


TEXT-FIG. 5—*Elsonella* sp. Lateral view.

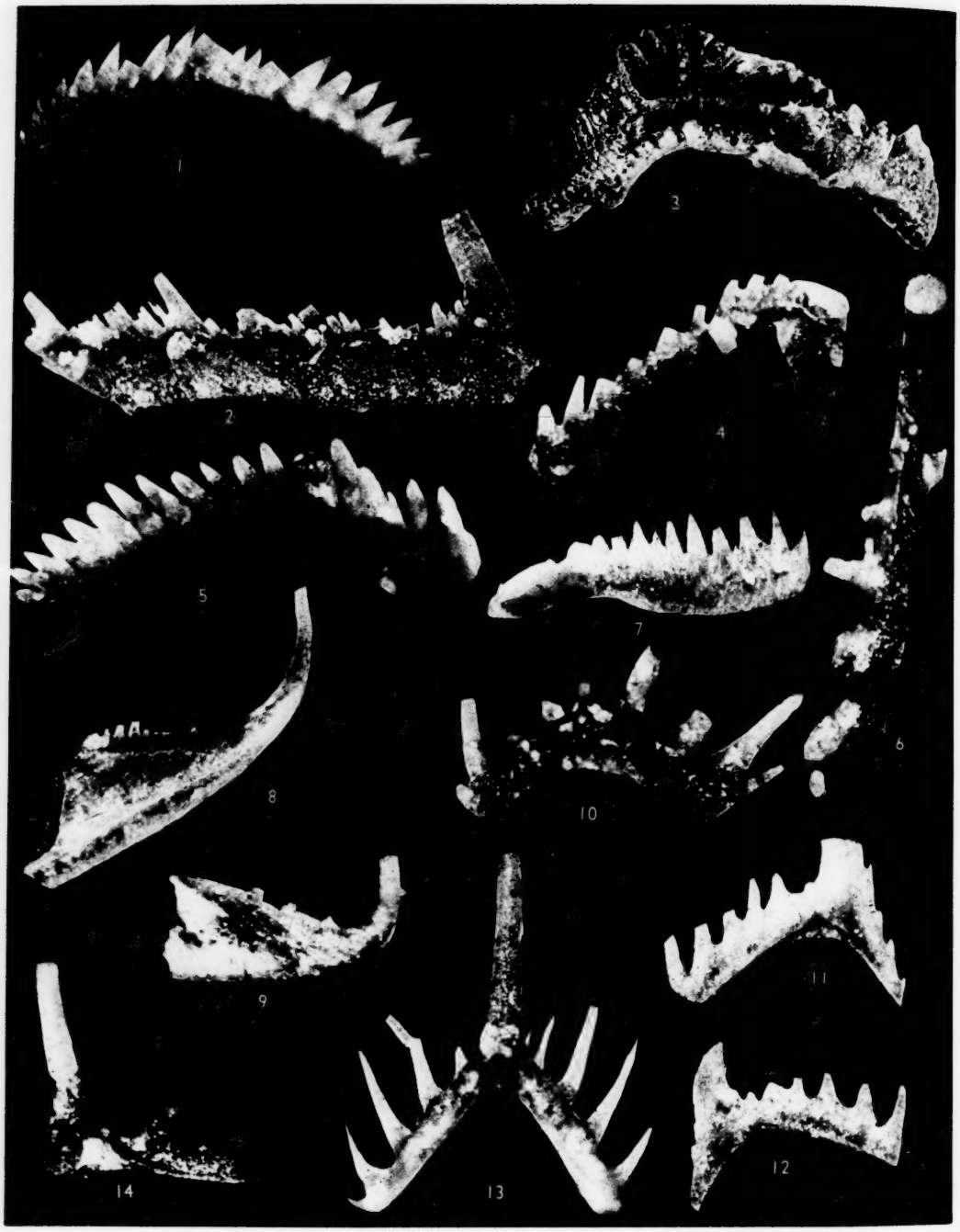
EXPLANATION OF PLATE 37

All photographs are retouched.

FIG. *1,2—Belodus triangularis* Stauffer. *1*, Lateral view, 2–9, ×40; *2*, lateral view; 3–26, ×85.
3—Belodus cf. *B. devonicus* Stauffer. Lateral view; 3–9, ×85.
4—Centrognathodus sp. Outer lateral view; 2–3, ×40.
5—Elsonella sp. Lateral view; 2–18, ×32.
6–10—Hindeodella sp. Lateral views, *6*, 1–14, ×40; *7*, 1–6, ×40; *8*, 1–7, ×40; *9*, 1–22, ×40; *10*, 2–6, ×40.
11—Spathognathodus ? sp. Lateral view; 1–3, ×40.
12,13—Paltodus sp. *12*, Lateral view; 3–18, ×40; *13*, lateral view; 3–18, ×40.
14—Lonchodina cf. *L. paucidens* Ulrich & Bassler. Lateral view; *14*, ×40.
15—Lonchodina alternata Branson & Mehl. Lateral view; 2–4, ×40.
16—Ligonodina cf. *L. flexuosa* Branson & Mehl. Lateral view; 2–5, ×40.
17–19—Polygnathus linguiformis Hinde. *17*, Oral view; 3–3, ×40; *18*, oral view; 1–24, ×40; *19*, aboral view; 2–21, ×40.
20—Ozarkodina firma (Stauffer). Lateral view; 1–11, ×100.
21—Polygnathus linguiformis Hinde. Oral view; 3–4, ×100.
22,23—Polygnathus varcus Stauffer. *22*, Aboral view; 1–5, ×85; *23*, oral view; 1–16, ×32.
24—Ozarkodina cf. *O. plana* Huddle. Lateral view; 2–1, ×100.
25—Ligonodina sp. Lateral view; 2–19, ×100.



Rhodes & Dineley



Rhodes & Dineley

either *Synprioniodina* or *Palmatodella*. Reference to Youngquist's illustrations (1945) suggest that this may be so in the case of one species (*E. secunda*) included by him in the genus *Elsonella*. The general form and symmetry of the type species (*E. prima*) would seem, however, entirely to exclude this species from either of the genera *Synprioniodina* or *Palmatodella*, both of which are defined by their asymmetry (Ulrich & Bassler, 1926, p. 41–42).

Only one specimen from the present faunas appears referable to this genus and it is difficult to base generic conclusions upon it. Study of this and Youngquist's illustrations suggest, however, that the genus is valid, but that Youngquist's original description may need to be slightly revised in the light of subsequent studies.

ELSONELLA? sp.
Pl. 37, fig. 5

A single specimen is tentatively included within this genus. It is not referable to either existing species and is therefore described in detail. Since only a single, incomplete specimen has been collected, a new species is not erected.

Bar symmetrically arched, the sub-apical angle being about 80°. Apical denticle, vertical in lateral view, slender, elongated; gently convex anterior and posterior faces, tapering to a point; gently flexed inwards along its length; at least twice as long as the largest lateral denticles of the bar. About seven denticles are symmetrically developed on each side of the apical denticle, which they resemble in general form: there is a gradual decrease in their size towards the distal ends of the lateral bars; the denticles are basally confluent, only their apices being discrete. The bar is deep, its depth being about equal to the length of the medial lateral denticles; the distal ends of the bar are spatulate; the sub-apical angle rounded, and its aboral edge thin, and blade-like; it is thickest near the base of the denticles. No obvious aboral flanges are developed.

Remarks.—This specimen differs from *E. prima* Youngquist in its lack of aboral flanges, the form and size of the cusp, the smaller number of lateral denticles and its considerably larger sub-apical angle. One lateral bar of the present specimen was broken after it had been described but before it was photographed.

Figured specimen.—Catalogue number 2·18.

Occurrence.—Sample 4

Genus HIBBARDELLA Ulrich & Bassler, 1926

Type species: *H.* (*Prioniodus*) *angulatus* (Hinde).

HIBBARDELLA ANGULATA (Hinde)

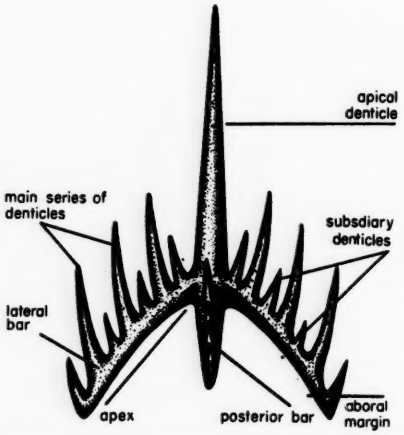
Prioniodus angulatus HINDE, 1879, p. 360, pl. 15, fig. 7; GRABAU, 1899, p. 151, fig. 33D; GRABAU & SHIMER, 1910, p. 244, fig. 1537h; BRYANT, 1921, p. 17.

Hibbardella angulata ULRICH & BASSLER, 1926, p. 37, pl. 3, fig. 1–4; BRANSON *in* Branson & Mehl, 1933, p. 141, pl. 11, fig. 16; HUDDLE, 1934, p. 16, 21–22, 78–79, pl. 3, fig. 6,7; CHADWICK, 1935, p. 316; BRANSON & MEHL, 1941, p. 175; ——— & ———, 1944, p. 241, pl. 93, fig. 73; GLAESSNER, 1945, p. 28, fig. 4, subfig. 15; CAMPBELL, 1946, p. 845; BOND, 1947, p. 21, 28, pl. 2, fig. 9; YOUNGQUIST, 1947, p. 100–101, pl.

EXPLANATION OF PLATE 38

All photographs retouched; all except *2*, *3* are ×85.

FIG. *1*—*Ozarkodina willsi*, n. sp. Lateral view; 2–13.
2—*Hindeodella* sp. Lateral view; 1–17, ×100.
3—*Polygnathus linguiformis* Hinde. Oral view; 1–21, ×32.
4—*Synprioniodina forsenta* Stauffer. Lateral view; 2–22.
5—*Ozarkodina willsi*, n. sp. Lateral view; 2–13.
6—*Hibbardella angulata* (Hinde). Lateral view; 1–25.
7—*Polygnathus varcus* Stauffer. Lateral view; 3–37.
8—*Belodus erectus*, n. sp. Holotype, lateral view; 1–4.
9—*Belodus* sp. Lateral view; 2–15.
10—*Lonchodina* cf. *L. disjuncta* Stauffer. Lateral view; 1–23.
11,12—*Prioniodus* cf. *P. idoneus* Stauffer. *11*, Lateral view; 3–35; *12*, lateral view; 3–33.
13—*Hibbardella*, n. sp. Anterior view, 2–10.
14—*Hibbardella* cf. *H. multidens* Ulrich & Bassler. Anterior view; 1–13.



TEXT-FIG. 6—*Hibbardella* sp. Posterior view.

24, fig. 16,17; YOUNGQUIST, HIBBARD & REIMANN, 1948, p. 53, pl. 15, fig. 2,13; THOMAS, 1949, p. 422; FAY, 1952, p. 100.

A single fragmentary specimen is referred to this genus. It agrees in all respects with Hinde's original description, although the median longitudinal groove of the apical denticle is only very feebly developed. Ulrich & Bassler (1926), Branson & Mehl (1933) and other subsequent workers have, however, noted the considerable variation in forms referable to this species.

Figured specimen: Catalogue number: 1–25.

Occurrence.—Sample 3

HIBBARDELLA cf. H. MULTIDENS Ulrich & Bassler
Pl. 38, fig. 14

Hibbardella multidens ULRICH & BASSLER, 1926, p. 38, pl. 3, fig. 8; HOLMES, 1928, p. 11; CHADWICK, 1935, p. 316; MILLER & YOUNGQUIST, 1947, p. 508, pl. 72, fig. 8,9, pl. 73, fig. 10,11; YOUNGQUIST, HIBBARD & REIMANN, 1948, p. 50, 53–54, pl. 15, fig. 10; FAY, 1952, p. 101.

A single fragmentary specimen exhibits the typically large sub-apical angle of the lateral bars, the discrete lateral denticles, the conspicuous sub-apical flange, and the long, slender fang. The fang is strongly compressed with sharp lateral edges, a convex posterior face and a flatter anterior face. It is strongly and continuously recurved. The lateral bars are also strongly antero-posteriorly compressed, with almost flat anterior and posterior faces. Only two lateral denticles are present on the broken lateral bar, and these are very widely spaced.

Figured specimen.—Catalogue number 1–13.

Occurrence.—Sample 4

HIBBARDELLA n. sp.
Pl. 38, fig. 13

A single specimen appears to represent a new species of the genus. This specimen was undamaged when photographed but was severely damaged during transportation. It is therefore illustrated but not described in detail nor given a specific name.

Remarks.—This specimen differs from *H. angulata* (Hinde) in its lack of a median groove on the apical denticle and in the development of subsidiary denticles on the lateral bars. It differs from *H. distans* Huddle in its lack of arching in the lateral bars and the absence of an "escutcheon" in the latter.

Figured specimen.—Catalogue number 2-10.

Occurrence.—Sample 4

Genus HINDEODELLA Ulrich & Bassler, 1926

Type species: *H. subtilis* Ulrich and Bassler.

HINDEODELLA spp.
Pl. 37, fig. 6–10; Pl. 38, fig. 2

Hindeodella is one of the most common genera of conodonts found in the limestones from the borehole. Each limestone studied contains representatives of the genus, but almost all the specimens are fragmentary. Partly because of this fact, no attempt is made to classify the specimens below the generic level. There are almost one hundred described species of the genus, many of which appear synonymous. The majority of these species are so loosely described that differentiation between them is a most speculative task, and one of questionable value. A few of the present specimens could be compared with three or four existing species. The genus itself is one with a long stratigraphical range, and appears to be of little use as an index fossil.

It is, however, noteworthy that the present representatives of the genus show a striking overall similarity to the species described by Huddle (1934) from the Upper Devonian New Albany Shale of Indiana.

Figured specimens.—Catalogue numbers 1-6, 1-7, 1-14, 1-17, 1-22, 2-6.

Occurrence.—Samples 1, 2, 3 and 4

Genus LIGONODINA Ulrich & Bassler, 1926

Type species: *L. pectinata* Ulrich and Bassler.

LIGONODINA cf. L. FLEXUOSA Branson & Mehl
Pl. 37, fig. 16

Ligonodina flexuosa BRANSON & MEHL, 1933, p. 199, pl. 15, fig. 28; COOPER, 1939, p. 390-391, 419, pl. 45, fig. 46; BRANSON, 1944, p. 163; THOMAS, 1949, p. 411, pl. 3, fig. 14.

A single specimen is compared with this species. It exhibits the characteristic form and proportions, including the stout antero-interior process, the wide posterior bar, with the typical excavation and the discrete, subcircular denticles, which are largest towards the mid-point of the bar. There are two minor features in which this specimen does not conform with Branson & Mehl's specific description. The distal portion of the anterior fang makes an acute angle with the posterior bar. The fang of this specimen is more complete than that of the holotype, which is described as forming approximately a right angle with the posterior bar. It appears that this is true only for the basal portion of the fang, and not for the recurved distal portion. The second minor difference is that the denticle of the antero-inferior process adjacent to the anterior fang is smaller than those which follow it.

Figured specimen.—Catalogue number 2-5.

Occurrence.—Sample 4

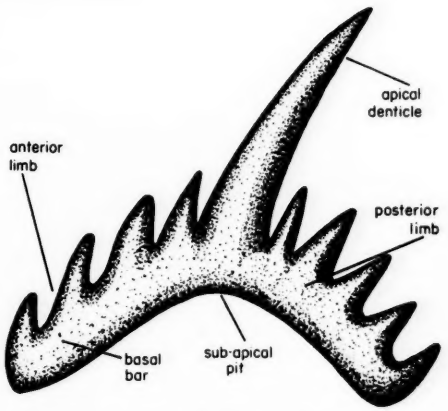
LONCHODINA Ulrich & Bassler, 1926

Type species: *L. typicalis* Ulrich and Bassler.

LONCHODINA ALTERNATA Ulrich & Bassler
Pl. 37, fig. 15

Lonchodina alternata ULRICH & BASSLER, 1926, p. 35, pl. 6, fig. 4; HOLMES, 1928, p. 13; CHADWICK, 1935, p. 315; FAY, 1952, p. 121.

Two fragmentary specimens are included within this species. Both are characterized by very conspicuous arching of the basal bar in both horizontal and vertical planes, where in each case the curvature of the distal ends amounts to about 90°. The basal bar is stout, blade-like in its distal portion, but increasing in width towards the largest denticle, below which the dorsal surface is deeply excavated. The denticles of the anterior bar, five or more in number, are discrete, somewhat compressed, with gently convex lateral faces and sharp edges, pointed, tending to increase in size towards the largest (apical) denticle. These denticles are continuously recurved inwards and backwards and the two nearest the apical denticle alternate with considerably smaller, sharply pointed denticles.



TEXT-FIG. 7—*Lonchodina* sp. Lateral view.

Figured specimen.—Catalogue number 2-4.

Occurrence.—Samples 3 and 4

LONCHODINA cf. L. PAUCIDENS Ulrich & Bassler.
Pl. 37, fig. 14

A single fragmentary, (immature?) specimen is compared with this species. Ulrich and Bassler's specific description is inadequate to define the species, but the present specimen is broadly similar to their illustrated specimen.

Figured specimen.—Catalogue number 1-14.

Occurrence.—Sample 4

LONCHODINA cf. L. DISJUNCTA Stauffer
Pl. 37, fig. 16

Lonchodina disjuncta STAUFFER 1938, p. 435, pl. 51, fig. 7; FAY, 1952, p. 122.

A few specimens appear to be comparable with this species. They agree with Stauffer's

description in general form, degree of arching, number and arrangement of denticles, and the form of the sub-apical pit. The apical denticle is, however, rather less strongly developed than Stauffer's description implies, but his holotype has the cusp broken at its base, and its general size may not be much greater than that of the present specimens. The denticles of the posterior limb of one of the present specimens tend to be laterally compressed, with sharp edges and gently convex faces.

Figured specimen.—Catalogue number 1–25.

Occurrence. Sample 4

Genus OZARKODINA Branson & Mehl, 1933

Type species: *O. typica* Branson & Mehl.

OZARKODINA FIRMA (Stauffer)
Pl. 27, fig. 20

Ctenognathus firmus STAUFFER, 1938, p. 425, pl. 48, fig. 2,6,15; FAY, 1952, p. 84.

One specimen shows a marked similarity in all its features to one of Stauffer's syntypes.

Figured specimen.—Catalogue number 1–11.

Occurrence.—Sample 2

OZARKODINA cf. O. PLANA (Huddle)
Pl. 37, fig. 24

Bryantodus planus HUDDLE, 1934, p. 75–76, pl. 10, fig. 8; FAY, 1952, p. 73.

Neither Huddle's description nor his illustration of this species are wholly diagnostic, but two of the present specimens appear to correspond closely with Huddle's description. Their general proportions, form and arrangement of the denticles and degree of curvature in a vertical plane all appear similar. The apical denticle in the present specimens is, however, rather longer than that of Huddle's holotype.

Figured specimen.—Catalogue number 2–1.

Occurrence.—Sample 4

OZARKODINA WILLSI Rhodes & Dineley, sp. nov.
Pl. 38, fig. 1,5

An *Ozarkodina* of slender proportions, with basal margin curved in a vertical plane below apical denticle so that the straight distal ends of the basal bar diverge at an angle of about 135°. Bar strongly laterally compressed, the length of the anterior portion being about half that of the posterior. Denticles, inclined posteriorly, closely spaced, but discrete for most of their length, more or less pointed. Apical denticle about twice the width of the other denticles. Subapical navel of medium size. Basal margin curved in a vertical plane below the apical denticle, so that at this point the basal margin is broadly concave. The distal portions of the basal bar are straight, and diverge at an angle of about 135°. The ends of the bar are spatulate. The whole unit is thin, laterally compressed, and sometimes very gently flexed in a horizontal plane. The unit is of slender construction, tending to be deepest at the anterior end, and tapering towards the posterior end. The point of flexure (marking the division of the bar into its anterior and posterior portions) is situated about one-third of the total length of the bar from the anterior end.

Oral denticles closely spaced, but discrete, of slender construction. The apical denticle about twice as wide at its base as the largest of the other denticles. All denticles are subparallel, being inclined posteriorly, are basally confluent but apically discrete, have sharp anterior and posterior edges and very feebly convex lateral faces, and have more or less sharply pointed apices. Anterior portion of bar bearing about eight denticles, which increase posteriorly in size and inclination. Posterior portion of bar bearing eleven or twelve similar denticles, which decrease in size posteriorly: those in the middle of the bar tending to be slightly larger than those nearer the apical denticle.

Aboral surface blade-like, with medium sized sub-apical navel, and excavated throughout its length by a very thin, but distinct, groove.

Types.—Catalogue number 2–13 (holotype), 2–2 and 2–11 (paratypes).

Remarks.—This species is readily distinguished from all others by its general slender form, the degree and position of vertical curvature, and the character of the denticles.

The species is named in honor of our teacher and friend, Professor L. J. Wills.

Occurrence.—Samples 3 and 4

Genus PALTODUS Pander 1856

Type species: *P. subaequalis* Pander.

PALTODUS sp.
Pl. 37, fig. 12,13

Two specimens are referred to this genus. One of these is complete and exhibits the typical "paltodid" basal outline, with expanded anterior portion and laterally compressed posterior portion. The basal anterior face is broadly rounded, the posterior edge is sharp. The whole cone is gently recurved, the apical portion making an angle of about 45 degrees with the base. The lateral faces exhibit the anterior expansion and posterior compression in the lower two-thirds of their length, but are otherwise unornamented.

The fragmentary specimen appears similar in general form to that just described.

Remarks.—There seems to be no possibility of these specimens representing fragments of the cusp (or fang) of more complex forms (e.g. *Ligonodina*, *Prioniodus* etc). The basal margins and general characters of both point clearly to their recognition as distacodids.

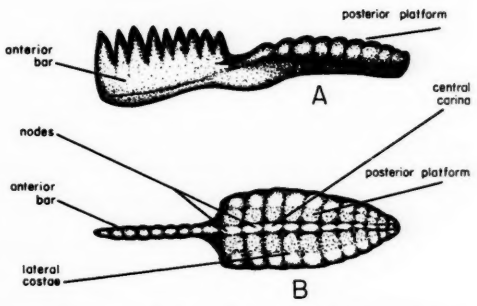
Figured specimen.—Catalogue number 3-18.

Occurrence.—Samples 2 and 4

Genus POLYGNATHUS Hinde 1879

Type species: *P. dubius* Hinde.

Hinde erected this genus to include "an animal possessing numerous minute and variously formed conodont teeth and similarly minute tuberculated plates grouped together, but of which the natural arrangement is not at present known" (1879, p. 361). He therefore proposed the genus for what he considered to be a natural assemblage of conodonts, which represented the remains of a single animal. Later workers have amended Hinde's description, interpreting the association of a number of diverse conodonts in one assemblage as purely fortuitous. Recent studies by Scott (1934, 1942), Schmidt (1934, 1950) Du Bois (1943) and Rhodes (1952), however, have indicated the possibility of such assemblages being natural, i.e. of representing the remains of single conodont-bearing animals. A study of Hinde's figures of the components of *P. dubius* suggests that possibly they



TEXT-FIG. 8—*Polygnathus* sp. (a) lateral view; (b) oral view.

may represent a natural assemblage of the "Type-A" described by Rhodes (1954).

Bryant (1921, p. 22) amended Hinde's definition as follows:

> In the present uncertainty, even as to the class of animals which bore these teeth, it seems to me advisable to retain Pander's generic names to the forms described by him and to restrict Hinde's genus *Polygnathus* to those crested crushing or tritoral plates so characteristic of his type specimen.

Roundy (1926, p. 13) agreed with Bryant in interpreting as coprolitic in origin the assemblage described by Hinde. He restricted the genus by selecting *P. dubius* Hinde as the type species, the specimen figured by Hinde (1879) as Plate 16, fig. 7.

Branson & Mehl (1933, p. 146–147) described a topotype specimen, which they referred to this species. However, they apparently (p. 146) accepted Hinde's illustration as representative of the type specimen. Ulrich & Bassler (1926, p. 43–45) redefined the genus, accepting *P. pennatus* as the type species. It is this later description which is at present accepted for the genus by the majority of conodont students.

POLYGNATHUS LINGUIFORMIS Hinde
Pl. 37, fig. 17–19,21; Pl. 38, fig. 3.

Polygnathus linguiformis HINDE, 1879, p. 367, pl. 17, fig. 15; FAY, 1952, p. 155.
Polygnathus crassus HINDE, 1879, p. 365, pl. 17, fig. 3; FAY, 1952, p. 152.
Polygnathus? simplex HINDE, 1879, pp. 367–368, pl. 17, fig. 18; FAY, 1952, p. 159.
Polygnathus peracutus BRYANT, 1921, p. 25, pl. 10, fig. 12; FAY, 1952, p. 157.
Polygnathus sanduskiensis STAUFFER, 1938, p. 438, pl. 53, fig. 27,36,37; FAY, 1952, p. 159.
(See Fay, 1952, Univ. Kans., Paleont. Contr., Vertebrata, Art. 3, for complete synonomies.)

Members of this species are among the most common conodonts from the Limestones numbers 3 and 4, some of them attaining a very large size. The largest measures approximately 2 mm. long. Individuals agree closely in form with those figured by Stauffer (1940). There is considerable variation in form during ontogeny, and a representative collection of individuals showing this variation is illustrated (Pl. 37, fig. 17–19,21). The variation is conspicuous in the following features: *a*, the curvature of the axis of the plate in a horizontal plane, which increases with age, so that in adult specimens the outer edge is in-flexed at a right angle: *b*, the curvature of the axis of the dental units in a vertical plane, which tends to increase with age: *c*, the relative length of the node-like central carina of the posterior plate, which tends to decrease posteriorly with age and *d*, the denticulation, represented both by the denticles and the nodes of the blade and carina, and by the costae of the platform, tends to become blunted and inconspicuous with increasing age.

Remarks.—Reference to Branson's illustration (1933, pl. 12, fig. 6,7) of Hinde's holotype indicates that *P. sanduskiensis* Stauffer is a junior synonym of *P. linguiformis* Hinde. Hinde's specimen of *P. linguiformis* was collected from the Genesee (Upper Devonian) of North Evans of New York.

It is difficult to separate such specimens as this from the genus *Siphonodella*. In its general form *S. duplicata* Branson and Mehl shows some resemblance to some species of *Polygnathus*. The development of the "spout-like" lateral rostral ridges in some specimens appears almost to bridge the gap between the two genera.

Figured specimens.—Catalogue numbers 1-21, -24; 2-21; 3-3, -4.

Occurrence.—Samples 3 and 4

POLYGNATHUS VARCUS Stauffer
Pl. 37, fig. 22,23; Pl. 38, fig. 7

Polygnathus varcus STAUFFER, 1940, p. 430, pl. 60, fig. 49,53,55; STAUFFER & THIEL, 1941, p. 229; FAY, 1952, p. 161.

The diagnostic feature of this species appears to be the flaring basal cavity, developed just anterior to the symmetrical, smooth or feebly ornamented platform, which rarely exceeds one-third of the total length of the whole unit, in the present specimens.

Figured specimens.—Catalogue numbers 1–5, 3–37.

Occurrence.—Sample 1

POLYGNATHUS XYLUS Stauffer

Polygnathus xylus STAUFFER, 1940, p. 430–31, pl. 60, fig. 42,50,54,65–7,69,72–4,78,79; STAUFFER & THIEL, 1941, p. 229; DOWNS & YOUNGQUIST, 1950, p. 671, pl. 87, fig. 15,16; FAY, 1952, p. 161.

This species is one of the most common in the present faunas, the many specimens agreeing closely with Stauffer's description. Unfortunately, Stauffer's twelve figures do not include any oral views. There is a tendency in some of the present specimens for the open, anterior end of the platform, adjacent to the anterior blade, to show a slightly asymmetrical development.

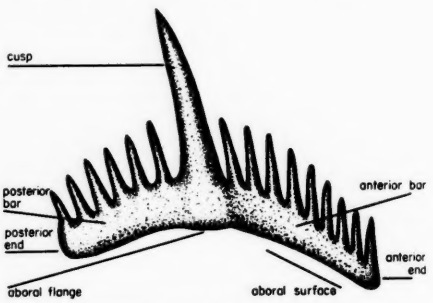
Occurrence.—Sample 1, 2, 3 and 4

Genus PRIONIODINA Ulrich & Bassler, 1926

Type species: *P. subcurvata* Ulrich & Bassler.

PRIONIODINA sp.

Two specimens appear to belong to this form but they are slightly different.



TEXT-FIG. 9—*Prioniodina* sp.

The essential features include the strongly curved bar, the 18 or so discrete, sub-equal denticles and the large cusp, situated near to the posterior end of the bar.

Occurrence.—Sample 4.

Genus PRIONIODUS Pander, 1856

Type species: *P. elegans* Pander (by subsequent designation).

The original description, an illustration of the morphological terms, and a discussion of the genus are given by Rhodes (1955). It is difficult to separate some of the present specimens from *Euprioniodina*, but since the anterior-aboral process is not "directed distinctly backwards" and bears denticles which are not "more or less discrete" (Branson & Mehl, 1933, p. 208), they are here referred to *Prioniodus*. This is in contrast to Ulrich & Bassler's earlier suggestion of the distinction between the two genera (1926, p. 29), but appears justified by Branson & Mehl's discovery of denticulation on the anterior-aboral process of the type species of the genus (1933, p. 129).

PRIONIODUS cf. P. IDONEUS Stauffer
Pl. 38, fig. 11,12

Prioniodus idoneus STAUFFER, 1938, p. 413,440, pl. 49, fig. 19; FAY, 1952, p. 172.

Stauffer figures only one specimen, the fragmentary holotype, and his brief description is inadequate to define the species fully. The description could well be applied to almost any member of the genus, but a number of specimens in the present collection resemble the holotype. The majority of them are in a perfect state of preservation, and are almost identical in morphology. They are therefore described in detail.

The unit is of stout construction, the posterior bar, the fang and the anterior-aboral process all being of massive proportions. Posterior bar straight or gently curved in a vertical plane. Aboral margin smooth and somewhat inflexed on outer lateral face; bevelled on inner face. Denticles of posterior bar crowded but discrete, major series about six in number, with irregular development of much smaller secondary denticles; denticles increase in size posteriorly and are inclined slightly forward, so that they lie sub-parallel to the cusp; bluntly pointed, strongly laterally compressed, with sharp anterior and posterior edges and convex lateral faces (the inner of which is more strongly rounded); these denticles may be slightly in-curved in some specimens. Main cusp also strongly laterally compressed, bluntly pointed, in-flexed more or less strongly; with conspicuous flaring inner aboral navel; inner lateral face more convex than outer; sharp anterior and posterior edges. Anterior-aboral process stout, distally pointed, forms a continuous straight anterior edge with the cusp; descreases in width distally; anterior edge bearing 3 or 4 denticles, their apices discrete, which are similar in form to and lie sub-parallel with those of the posterior bar and anterior process.

Figured specimens.—Catalogue numbers 3–33, –35.

Occurrence.—Sample 1

Genus SPATHOGNATHODUS Branson & Mehl, 1941

Type species.—*S. primus* (Branson & Mehl).

SPATHOGNATHODUS? sp.
Pl. 37, fig. 11

A single fragmentary specimen, apparently representing this genus, is present in Sample 1. It displays the basally coalesced, laterally compressed oral teeth, blade-like bar and flaring basal navel characteristic of the genus.

Figured specimen.—Catalogue number 1–3.

Occurrence.—Sample 1

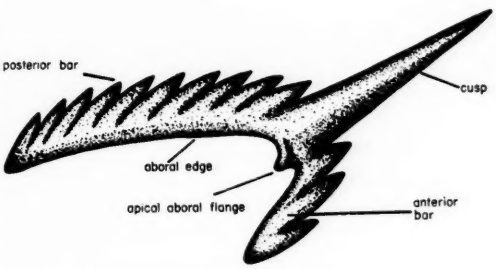
Genus SYNPRIONIODINA Ulrich & Bassler, 1926

Type species: *S. alternata* Ulrich & Bassler.

SYNPRIONIODINA sp.
Pl. 38, fig. 4

Figured specimen.—Catalogue number 2–22.

Occurrence.—Sample 4



TEXT-FIG. *10*—*Synprioniodina* sp.

"EGG CASES"?

Stauffer (1940, p. 434) describes egg-cases? from clay associated with the Devonian limestones in Minnesota. A few similar spherical bodies occur in each of the limestones yielding conodonts at Bishopsteignton. They are remarkably uniform in size being about 6 mm. in diameter, and are somewhat larger than Stauffer's specimens and with a relatively larger central cavity. A faintly concentric structure is apparent in broken specimens. The spheres sink in bromoform (specific gravity 2.9) and appear to resemble conodonts in the physical characters of their substance. They occur only in the limestones yielding conodonts.

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LATE MISSISSIPPIAN FAUNA FROM THE REDOAK HOLLOW FORMATION OF SOUTHERN OKLAHOMA, PART I

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ABSTRACT—The described invertebrates, mostly bryozoans and assorted boring organisms, come from the Redoak Hollow formation of the Ardmore basin, southern Oklahoma, and are of latest Chester age. Status of fossil boring sponges is reviewed, and two new species described. Three transitional forms between *Rhabdomeson* and *Rhombopora* are established; also the presence of a *rhabdomesontid* axial tube in *Streblotrypa nicklesi* is recorded. Two new genera, one subgenus, and twenty-six new species and varieties of bryozoans are introduced. The stratigraphic distribution of late Mississippian species of *Archimedes* is summarized. This is the first part of a monographic description of the Redoak Hollow fauna.

FOREWORD

By C. W. TOMLINSON

IN THE following paper Elias reports on a heretofore undescribed fauna of many species from the Goddard shale, "Pennsylvanian Caney," of the Ardmore Basin in southern Oklahoma, a formation previously assigned to the lower part of the Springer series (Cheney, 1945) or to the Springer group of the Morrow series (Moore et al., 1944). It was then thought to be possibly of earliest Pennsylvanian age. Although some elements of this fauna show closer resemblance to Pennsylvanian than to Mississippian types hitherto known, Elias believes it to be of late Mississippian age.

Fossil material heretofore described from Springer rocks has been pitifully meager. In the early work by Goldston (1922) and by Girty & Roundy (1923), unidentified coiled cephalopods from a single locality north of Berwyn (Gene Autry) constituted the only collections surely obtained from Springer strata. Harlton described three species of foraminifers (1927, 1928) and a single ostracode (1927). Bradfield (1935) added another foraminifer. Waters (1925) listed from the Berwyn area and one other Springer locality a total of nine forms: two brachiopods, a bryozoan, five cephalopods, and a plant *Cordaites*. Tomlinson (1929) reported *Calamites* from two of the Springer sandstones on the Caddo anticline, north of Ardmore. The lists of these seven authors totaled no more than fifteen forms; all probably came from higher strata than the Redoak Hollow member of the Goddard, the source of the fauna now described by Elias.

Over the past ten years Elias has obtained fossil material from eight or more zones scattered through the section of rocks which has borne the name Springer (formation, group, or series). These are listed by him in a recent paper (Elias, 1956).

Several years ago a field party led by Dr. Chas. E. Decker discovered a varied fossil fauna in a "Springer" sandstone in Section 19, T. 2 S., R. 1 W., two miles north of the village of Milo, Carter County, Oklahoma, in the northwestern part of the Ardmore basin; but it has not previously been described. In this fauna, from collections by Tomlinson, Elias now reports the following forms:

Brachiopods	21 genera,	33 species
Bryozoans	16 genera,	41 species
Pelecypods	24 genera,	37 species
Gastropods	16 genera,	21 species
Ostracods	15 genera,	23 species
Other forms	28 genera,	32 species
Total	120 genera,	187 species;

(including 6 new genera and subgenera, 84 new species, and 12 new varieties)

The material studied by Elias came from four localities, as follows:

1. Redoak Hollow sandstone, NE-SW-SW-SW Sec. 19, T. 2 S., R. 1 W. Two miles north and $\frac{5}{8}$ mile west from the village of Milo, Carter County, Oklahoma. On bare saddle of NW-trending ridge, just southeast of its wooded crest. Float only.

2. Redoak Hollow sandstone, SE-NW-NE-SE Sec. 30, T. 2 S., R. 1 W. One mile SE of *1*. On bare nose of ridge, just north of woods. Both outcrop material and float.

3. Redoak Hollow sandstone, SE-NW-NE-NE Sec. 30, T. 2 S., R. 1 W., ½ mile north of *2*. Soft ferruginous sandstone at head of ravine which drains east. Outcrop material only.

4. Sandstone, probably Redoak Hollow but possibly slightly lower. Near SE corner SW-NW-SW Sec. 19, T. 2 S., R. 1 W. ½ mile north of *1*. In and west of pasture road, just north of creek crossing. Outcrop material only.

At locality *1*, and also at *2*, the fossils are found on an open, grassy section of a ridge, whose higher crest nearby along the strike is heavily wooded. Massive unfossiliferous sandstone up to 25 feet in exposed thickness outcrops in the oak woods. The disappearance of the oaks, the dwindling of outcrops to ledges a foot or two thick, and the lower elevation of the ridge crest, all suggest that the local abundance of fossils may be environmentally related to reduction in volume of sand where the fauna flourished.

No patches of equally abundant fossil remains in the Springer are yet known outside of this two-square-mile area, except for the Target limestone discovered by Bennison (1954) much higher in the section. Their occurrence here in a single member is not surprising. Such an abundance of fossils repeated at successive times in different sandstone members within the same small area, and there only, would be difficult to explain. Exposures are not sufficiently continuous to make it certain that all four localities are in the same member. It is likely that they are; though, if so, the member is probably displaced locally by transverse faulting, such as is visible in the Mississippian and older limestones of the Arbuckle Mountains, near by.

All four collections are certainly from sandstones older than the Rod Club sandstone, and therefore within the Goddard shale: probably in the lower half of it. This statement is based on the proximity of the fossil localities to outcrops of the Mississippian Caney shale and Sycamore limestone. Unfortunately only a few feet of strata conformably overlying the Redoak Hollow are exposed in the immediate vicinity of the fossil sites. The entire pre-Pontotoc Pennsylvanian section is covered unconformably by younger (Pontotoc) strata of early Permian or latest Pennsylvanian age.

The general structure of the Springer sandstones in the neighborhood of these four fossil localities is that of a steep anticlinal nose plunging southeastward; dips average 50°. The east flank of this fold drops into a narrow syncline, also plunging southeast, which lies between the anticline and the mountain front to the northeast. Most of the sandstone outcrops are distributed around a sharp S-curve which outlines the southeast plunge of the anticline and the complementary northwest end of the adjacent syncline.

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ACKNOWLEDGMENTS

The present study of the invertebrates from the Redoak Hollow exposed near Ardmore, Oklahoma, has been conceived and sponsored by Dr. C. W. Tomlinson of Ardmore, who has also paid for the cost of reproduction of the plates. The faunal studies were executed by me intermittently during the years 1946–1956. Dr. G. E. Condra, State Geologist of Nebraska, generously allowed use of laboratory, photographic, and library facilities. The whole fossil collection recovered, including the described types, is deposited at the Nebraska Geological Survey.

Professor Betty Kellett Nadeau of Washington University, St. Louis, helped in the study of some of the difficult molds of the ostracodes in the collection. Subsequent to the consultation with her, these forms were compared with some types deposited at the National Museum, through the courtesy of Dr. R. S. Bassler. Dr. Stewart A. Levinson of the Humble Oil and Refining Co. read the chapter on the ostracodes. Specimens of a new genus of brachiopods, *Pseudokeyserlingina*, were sent for examination to Professor C. O. Dunbar who contributed to the form's morphologic and taxonomic treatment. He and Professor K. E. Caster read the whole manuscript and made many useful suggestions. Oral discussion about taxonomic significance of muscle-scars in *Leptodesma* and related pelecypods with Professor N. D. Newell of Columbia University was helpful in classification of these pelecypods. The author, alone, is responsible for all final identifications and descriptions.

The described fossil forms have been obtained chiefly from specimens collected by Dr. C. W. Tomlinson. Additional material was also subsequently collected by Dr. Tomlinson, Dr. Maynard White, and the author in the fall of 1946 and again in 1955. Some of this additional material represents new or more nearly complete specimens than those originally recovered. All identified forms based on these collections constitute the list of invertebrates from the Redoak Hollow. They are described in the systematic part of this report and subsequent portions.

INTRODUCTION

The Redoak Hollow fauna is an assemblage of marine invertebrates comparable in richness and diversity with the best-known late Paleozoic invertebrate faunas of the southern Midcontinent. An apparent link is provided between marine life of the late Mississippian and early Pennsylvanian seas in this region.

The Springer, where the Redoak Hollow was originally thought to belong, has been customarily classified with the Lower Pennsylvanian. At first it was expected that comparison with previously described Pennsylvanian forms would be sufficient to identify the fossils. As the study progressed, it became evident that this comparison was not sufficient; many forms in the Redoak Hollow show stronger affinities with Mississippian rather than Pennsylvanian forms. A critical analysis of the changes in the marine invertebrates that occurred at the end of Mississippian and at the beginning of Pennsylvanian times was involved. Where both Mississippian and Pennsylvanian sediments occur in other regions of America they are usually divided by pronounced erosional unconformities. Consequently, the fossils collected from these localities contain comparatively few forms that are common to both systems. Because this situation prevails in most areas where the sediments of these two periods outcrop, many geologists take it for granted that the change of fauna at the junction of these periods is invariably pronounced. It was generally believed that genus *Archimedes* ended abruptly at the close of Mississippian time, and that many

other common Mississippian genera, such as *Diaphragmus*, *Productella*, *Orthotetes*, etc. disappeared completely. Likewise, it was also generally assumed that the beginning of Pennsylvanian time was coincidental with the first appearance of such brachiopod genera as *Meekella*, *Derbya*, *Squamularia*, and others. However, more critical paleontologists have never been content with the idea of a supposed abrupt faunal change at this time, as many facts pointed to the survival into Pennsylvanian time of forms originally thought to be restricted to the Mississippian only. The genus *Pentremites*, so common locally in upper Mississippian formations, has also been found in abundance in Morrow beds (Mather, 1915). This relationship is also true in regard to bryozoan genera, such as *Prismopora*, and others. Even the concept of an abrupt disappearance of *Archimedes* at the end of Mississippian time has been disproved by the fairly abundant occurrence of this genus in sediments of Desmoinesian age in central Utah.

The Redoak Hollow also contains numerous species whose Pennsylvanian affinities tend to indicate its placement in the Pennsylvanian system. A somewhat similar combination of Mississippian and Pennsylvanian faunas is known from the upper Morrow fauna of Arkansas and Oklahoma, and it was regarded "transitional between the faunas which have been considered typical of the later Mississippian and of the earlier Pennsylvanian times" (Mather, 1915, p. 67). At the end of Mather's comprehensive analysis of the fauna, he lists within it 20 species which he considers a "Residual Mississippian element," as compared with 49 (or about two and a half as many species) which he regards as a "Proemial Pennsylvanian element."

It was more recently suggested that a number of genera of "decided Pennsylvanian aspect" occur in the Pitkin limestone of Arkansas (Easton, 1943, p. 126–127). While it was concluded that the Pitkin is of latest Chester age, its upper part was thought to be of even later age than the Kinkaid of Illinois, though still within the Mississippian. Thus the Pitkin fauna may be considered to bridge the gap between known late Mississippian and earliest Pennsylvanian (Morrow) marine faunas.

As the concept of supposed abrupt change from the Mississippian to Pennsylvanian marine faunas is weakened by the discoveries of more and more "mixed" border faunas, the problem of establishing reliable paleontological criteria for assignment to one or the other becomes increasingly difficult. Thus, the present study of the Redoak Hollow fauna involved a critical comparison with Mississippian as well as Pennsylvanian fossils known from America and from the principal localities of Western Europe. As work progressed it was noted that some major taxonomic groups represented in the fauna show a greater affinity to the corresponding groups in the Mississippian, while others are closer to those in the Pennsylvanian. In the first category belong the bryozoans, brachiopods and gastropods; and in the second, the pelecypods. It therefore seemed advantageous to scrutinize affinities of each group of invertebrates separately, and then to try and explain why the predominant affinities of one group are different from those of another. Furthermore, it has been observed that occasionally some groups show greater affinities with their foreign rather than American representatives. Such was the conclusion in regard to the corals of the Pitkin limestone of Arkansas by Easton (1943, p. 128–141). He believed that these corals show affinities with the Lower Carboniferous corals of the British Isles and Western Europe, and that the coral fauna as a whole is unlike the nearby ones in the Chester and earlier Mississippian of Illinois and adjacent regions. A number of pelecypods (and some gastropods) in the Redoak Hollow fauna show strong affinity and even specific identity with some forms low in the Upper Carboniferous of Scotland.

PRESERVATION

Only a few of the invertebrates in the collections from the Redoak Hollow have original shell material preserved; for example: the single chitinous valve of *Lingula*, some calcareous valves of the brachiopods and pelecypods, and a few isolated crinoid columnals. When preserved in this fashion the specimens usually do not have their surfaces well exposed and the matrix adheres to them tightly. Thus, the specimens which have their shells preserved, are, in spite of this advantage, only occasionally useful for a detailed morphological study.

The greatest part of the fossil material in the Redoak Hollow is in the form of external and internal molds. When the matrix of such molds is limonitic, it reflects the finest details of the shells whose calcareous substance is completely removed. Less well preserved are the molds in the fine- to medium-grained sandstone, but these are also occasionally useful, and a few species are here described from such molds only. Because most invertebrate fossils have been previously described and illustrated from their exterior, and not from molds, the comparison and identifications of the present molds is difficult. Casts from these molds can be prepared, but in the process the fine fragile structural details in the natural molds are damaged. This statement particularly concerns some brachiopods and pelecypods whose calcareous shells are penetrated by various delicate borings preserved as fine-textured limonite molds.

COMPARISON WITH RELATED FAUNAS OF AMERICA

As shown on Table 1, the bulk of the fauna is about equally divided between "molluscoids" and mollusks. Bryozoa are represented by a larger number of species than any other group, but the Brachiopoda belong to a larger number of genera than the Bryozoa, and the Pelecypoda are represented by a larger number of genera than any other group. The total number of identified genera, species, and varieties of the invertebrates from the Redoak Hollow is comparable in magnitude with the number of the same taxonomic units described or reported from the major stratigraphic divisions above and below it.

Only records published after 1910 of better-known pre-Redoak Hollow faunas from the southern Midcontinent are considered. Faunas from the Moorefield shale and the overlying Batesville sandstone of northern Arkansas were described by Girty (1911, 1915). Girty correlated these formations with the St. Genevieve limestone of southern Illinois and adjacent territory, while Easton (1942, p. 77) correlated them with the St. Louis, St. Genevieve and lower Chester. Combining the lists of fossils identified by Girty from the two above mentioned formations accounts for the 89 genera and 178 species or varieties entered in Table 1. The marine invertebrate fauna of the Pitkin limestone of Arkansas was more recently recorded by Easton (1942, 1943),

TABLE 1.—NUMBER OF THE KNOWN GENERA AND SPECIES OF THE INVERTEBRATES IN PRE-REDOAK HOLLOW, REDOAK HOLLOW, AND POST-REDOAK HOLLOW SERIES OF THE SOUTHERN MID CONTINENT

Invertebrate Groups	Paradise of Arizona (Hernon, 1935)		Moorefield & Batesville of Arkansas (Girty, 1911, 1915)		Pitkin ls. of Arkansas (Easton, 1943)		Mayes, Fayetteville and Pitkin of Oklahoma (Snider, 1915)		Redoak Hollow at Ardmore of Oklahoma (Elias, 1956)		Upper Morrow of Ardmore, Oklahoma (Girty, Roundy, 1932, Harlton, 1927, Waters, 1927, Bradfield, 1935)		Upper Morrow of Arkansas and Oklahoma (Mather, 1915)	
	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.	Gen.	Spec.
Foraminifera		*	2	2*	1	1*		*	4	4	7	11		*
Porifera		*	1	1*		*		*	2	4		*		*
Anthozoa	1	1*	2	2*	8	11	3	3	none		5	5	9	11
Blastoidea	1	1			1	3	1	1	none				1	2
Crinoidea	1	1*	1	1*	15	23	1	1*	6	6*	3	3*	5	7*
Echinoidea		*		*	1	1		*	1	1		*	1	1
Annelida		*	1	1	1	1		*	2	2		*		*
Bryozoa	13	37	11	18	15	30	7	19	19	42	8	8	14	37
Brachiopoda	20	54	23	52	27	48	29	56	22	36	11	29	19	48
Pelecypoda	15	32	20	54	17	35	17	36	26	37	15	28	15	29
Gastropoda	9	12	13	20	24	30	19	15	16	21	14	22	12	14
Scaphopoda	1	1	1	1	1	1		*	2	2		*		*
Cephalopoda	3	3	8	18	6	9	4	5	7	8	4	4	2	4
Trilobita	1	1*	1	1*	3	4	1	2*	1	1*	1	1*	1	2*
Conchostraca		6*		*		*		*	2	3		*		*
Ostracoda	1	1*	5	7*	3	3*		*	17	25	20	49		
Total	66	150	89	178	123	200	76	138	127	192	88	160	79	155

* Data incomplete.

this unit contains the largest number of genera (123) and species (200) in the known late Mississippian faunas of the southern Midcontinent. Unfortunately, only 30 Pitkin forms, all as new species, were completely described by Easton (1943), and six species of crinoids from this limestone were described by Laudon (1941). Of the remaining 167 forms, 96 forms were illustrated but not described by Easton, for the most part by single natural-size half-tone illustrations. Condra & Elias (1944-A) described five species of Pitkin *Archimedes*, four as new.

The two late Mississippian faunas described by Girty and by Easton come from the outcrops in northern and western Arkansas, about 200 to 300 miles northeast of the location of the Redoak Hollow fauna. Directly to the north and northeast of the Redoak Hollow location the faunas from the Mayes, Fayetteville, and Pitkin limestone of Oklahoma described by Snider (1915) were secured. The number of forms in the combined lists from these three formations is listed, 76 genera and 138 species, thirty as new. Of these, 57 species were briefly described but inadequately illustrated.

A fourth fauna of late Mississippian age is known from the Paradise formation of Arizona, some 700 miles west-southwest of Ardmore. In all, 66 genera and 150 species were recorded by Hernon (1935). Of these, only 40 species and varieties are described and satisfactorily illustrated, 13 as new.

The Morrow fauna, stratigraphically directly above the Springer series, is known largely from the two principal areas of outcrop: at Ardmore in Oklahoma, and in western Arkansas plus the adjacent part of eastern Oklahoma. The fauna from the vicinity of Ardmore is known from the lists of fossils identified by Girty & Roundy (1923). A somewhat larger number of foraminifera and ostracoda were subsequently described from the same area of outcrops by Harlton (1927) and Waters (1927). A more nearly complete collection of ostracodes from the same area was described and well illustrated by Bradfield (1935). The combined number of the identifications of this fauna referable to the lower Dornick Hills series, upper Morrow, comprises 88 genera and 160 species.

A second fauna of Morrow age from the Hale formation, Brentwood limestone, and Kessler limestone of western Arkansas and northeastern Oklahoma was described and illustrated by Mather (1915). Although the half-tone illustrations of these forms are inadequate in some cases, good descriptions and dimensions give an understanding of most of the species. Some of the pelecypods were subsequently revised and redescribed by Newell, and Mather's types of fenestrate Bryozoa have been forwarded to the Nebraska Geological Survey and restudied by me. Mather's monograph on the upper Morrow fauna is still the only adequate publication dealing with all groups of its megascopic invertebrates. The total number of the forms described is 155 species in 79 genera.

The faunas listed on Table 1 are generally comparable to each other in number of genera and species. This generalization applies particularly to the largest groups of invertebrates represented: Bryozoa, Brachiopoda, Pelecypoda, and Gastropoda. However, there are also some notable differences in the proportions of genera and species in various groups of each fauna. Some of these differences are probably the result of individual attitudes in taxonomy by the paleontologists who studied them; other differences may be of real significance. Thus, a proportionately small number of Bryozoa in the lists of identified fossils by Girty, in both the pre-Pitkin Mississippian fauna of Arkansas and the upper Morrow fauna at Ardmore, results from an inadequate treatment of the fenestrate Cryptostomata in his collections; his treatment of other Bryozoa is ample or quite profound. A similar explanation applies to the scarctiy of identified bryozoa in the lists published by Snider; he remarks that his lists of Bryozoa are "not complete" (1915, p. 32,37), or that the Bryozoa in some of the collections were "not studied" (p. 41).

Differences in taxonomic attitude of the paleontologists who studied these faunas are responsible for the diverse proportion of the identified genera to the identified species. In all early identification-lists there are an average of two species for each genus; in the two later lists, one by Easton for the Pitkin limestone and that made here for the Redoak Hollow, the proportion of genera to species is *circa* 2:3. This relationship reflects the modern trend of splitting comprehensive

genera into subgenera or restricted genera; particularly for corals, brachiopods, pelecypods and gastropods. Such is not the case in the fenestrate bryozoa, for such genera as *Fenestella*, *Archimedes*, and *Polypora* remain as comprehensive as at the time when Ulrich published his famous monograph (1890); the number of species in these and related bryozoan genera has steadily increased. Taking these considerations into account, it is possible to evaluate the significant similarities and differences in the faunas compared. It appears that the number of genera and species of Bryozoa is about the same throughout late Mississippian and early Pennsylvanian times , and so is the proportion of genera to species (*circa* 1:2 to 1:3). The number of brachiopods in Pitkin time was also about the same, but Redoak Hollow time was marked by a considerable reduction in number of both genera and species. The reduced number apparently continued into medial Morrow (early Dornick Hills) time of the Ardmore basin; elsewhere, in eastern Oklahoma and western Arkansas, the number of species of brachiopods at this time again became as large as in most Mississippian faunas. The number of genera and species of pelecypods was constant throughout late Mississippian and early Pennsylvanian time, perhaps with only slight reduction of the number of species in Redoak Hollow and later times. An unusually large number of species of pelecypods is noticeable in the pre-Pitkin Mississippian of Arkansas, perhaps a provincial characteristic of this fauna. The number of genera and species of gastropods in various faunas is somewhat more variable than that of the other invertebrates discussed; this fact may reflect inadequacy of collecting, preparatory work, and interest rather than true variability in distribution. The number of known cephalopods in the discussed faunas is even more variable; discovery of cephalopods, particularly in ammonites which are subjected to a fairly intensive search depends largely on chance; their occurrences are usually rare and narrowly localized. Great differences in the number of the identified ostracodes in the discussed faunas seems largely due to variability in skill and determination of the collectors.

Among other groups of organisms, the absence in the Redoak Hollow of corals and blastoids may be significant. This lack is certainly not because of insufficient search; not a single fragment of these fossils has ever been observed although much material has been broken and examined. Similarly, not a single *Pentremites* has been recorded by Girty in the pre-Pitkin upper Mississippian of Arkansas or in the medial Morrow of the Ardmore basin. The complete absence of corals in this fauna seems rather an exclusive negative characteristic; other fossils customarily associated are fairly common: crinoids, bryozoans, and larger brachiopods. Perhaps the marked decrease in the number of genera and species of brachiopods in the Redoak Hollow can be correlated with the disappearance of corals. The phenomenon could have been due to a local moderate shallowing of the sea or to muddying of its waters, or both.

TAXONOMIC CONSIDERATIONS

Some paleontologists believe that identification of fossil genera and species is highly subjective, and that opinions in fossil

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EXPLANATION OF PLATE 39

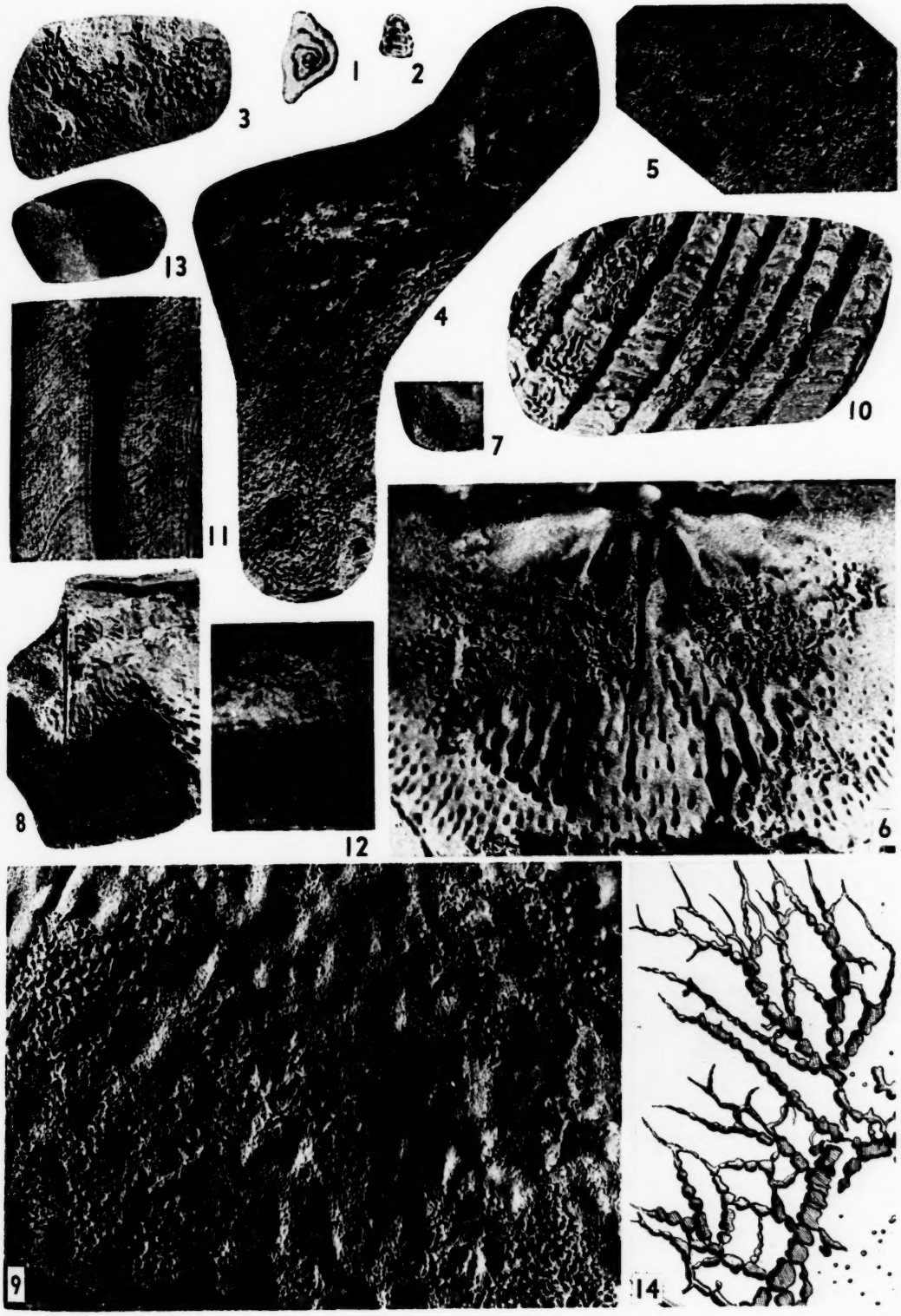
FIG. *1*—*Ammovertella*? sp., ×25.

2—*Textularia* cf. *grahamensis* Cushman & Waters, ×25.

3–10—*Cliona paleodendrica*, n. sp. *3–6*, Natural cast of excavations in shell of *Chonetes*, n. sp. *3*, ×10; *4*, ×2; *5,6*, ×10. *7*, Natural casts of excavations in shells of *Chonetes*, n. sp., and external mold of encrusting *Ptychocladia bassleri*, n. var., ×20. *8,9*, Holotype. Natural casts of excavations in dorsal valve of *Buxtonia semicircularis* (Sutton & Wagner); *8*, ×2; *9*, ×10. *10*—Natural casts of excavations in shell of *Orthotetes* (*Derbyia*); also natural casts of *Condranema* sp. (to the right) and of enigmatic transverse holes; ×10.

11–13—*Cliona stellata*, n. sp. *11,12*, Natural casts of excavations in shell of *Spirifer*, n. sp., ×10 and ×20. *13*, Holotype. Natural casts of excavations in unknown shell, ×10.

14—Living *Cliona corallinoides* Hancock in *Pecten maximus* shell. After Hancock.



Maxim K. Elias

Maxim K. Elias

taxonomy are now, and always will remain, divergent and irreconcilable. There is some truth in this claim, but an extreme individualistic attitude among paleontologists is an exception rather than rule, and reasonable uniformity in taxonomy has gradually been achieved in modern paleontology. If this were not the case, it would hardly be possible to keep paleontologic taxonomy on a reasonable scientific and serviceable level. In addition, some paleontologists maintain that identification of new material with previously described species can be assuredly established only by comparison with original types, and not merely with their published illustrations and descriptions. Again, there is an element of truth in such statements, but only in exceptionally difficult cases of identification; paleontological practice shows that identifications are being made satisfactorily by comparison with illustrations and descriptions. When an attempt is made to compare as large and divergent a fauna as that from the Redoak Hollow with previously-known similar faunas it is important to investigate whether these records are sufficiently complete and accurate to meet present-day standards. It was found that the taxonomy of the smallest units (species and varieties) of these forms is reasonably well stabilized. In most of the few cases of erroneous or doubtful identifications these have been corrected or improved upon in subsequent analytical investigations and revisions by specialists in the respective invertebrates. Some ranking specialists have also gradually revised generic status of these fossils, and it is in the renaming of genera where the greatest changes have occurred.

Bryozoa remain an exception in the nearly universal trend toward splitting of old genera, particularly the fenestrate Cryptostomata. Here, the comprehensive genera *Fenestella*, *Polypora*, and *Septopora* remain in their old status, but an attempt is now being made to split them into subgenera and groups on the basis of spacing of dissepiments and of structure of carina (in *Fenestella*), and also on various zoarial features. It seems advisable, at least for the present, not to elevate these subgeneric and section subdivisions (Elias & Condra, 1957) to generic rank because it would add further difficulty in taxonomic handling of these common bryozoa. Past experience shows that most paleontologists have been reluctant to identify species and usually identified only genera when handling fenestrate Cryptostomata (now Fenestrata). There has been a recent tendency to differentiate the massive, crustose and ramose Trepostomata into a number of genera on the evidence of various internal details. However, an effort to reduce the seemingly large number of genera in this group has also been made.

Subgenera in relation to genera.—Many paleontologists do not use the taxonomic category of subgenera, for soon after introduction, a subgenus is usually elevated to full generic rank. With the gradual advance of our knowledge of the evolution of various fossil organisms there arises a new need for

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EXPLANATION OF PLATE 40

FIG. *1*—*Cliona paleodendrica*, natural casts of its poorly developed (immature?) excavations in the shell of *Spirifer casteri*, n. sp.; ×10.

2—*Cliona fenestralis*, n. sp., holotype. Natural cast of its excavation in a fragment of shell of a productid; ×20.

3—*Clionolithes* cf. *C. radicans* Clark. Natural cast of its excavations in the shell of *Spirifer casteri*, n. sp.; ×10.

4—*Spirorbis elegans*, n. sp. External mold of upper side, ×10.

5,6—*Cornulites inelegans* Hyde. External and internal molds of same individual, with longitudinal flat scar of attachment well developed upon the internal mold, ×10.

7,8—*Bascomella* cf. *B. gigantea* Morningstar, molds in *Spirifer*, n. sp., ×20 and ×10.

9—*Condranema* cf. *C. magna* Condra & Elias, molds in *Acanthopecten*, n. sp., ×10.

10,11—*Seminolithes clarkei*, n. sp., molds in *Buxtonia semicircularis*, *10*; and in an *Orthotetes*? *11*, ×10.

12—Pathologically swollen columnal of unknown crinoid, ×2.

13—*Vinella bilineata*, n. sp., molds in unknown pelecypod, ×10.

14—*Tabulipora* cf. *tuberculata* Prout, encrusting crinoidal columnals, ×10.

the use of some well established generic names in a subgeneric sense. A few species among bryozoans and brachiopods, for example, combine the features of two (or more) genera of certain lineage; a phenomenon which indicates that the later genus passed through an evolutionary stage of inception. The existence of such a condition in the phyletic history of at least some genera has already been recognized by some of the most experienced paleontologists. Girty finds considerable variation in the hinge apparatus of *Orthotetes* from the Batesville sandstone of Arkansas; some individuals approach the hinge typical of *Orthotetes*, and others the hinge of *Derbyia*. *Orthotetes* is an older (Mississippian) genus, from which the genus *Derbyia* evolved. Species from the earlier Mississippian horizons have been placed in *Orthotetes* unhesitatingly; all species of the *Orthotetes-Derbyia* group are usually placed in *Derbyia* when collected from the Lower Pennsylvanian. It is suggested that the species in the transitional stage of evolution from *Orthotetes* to *Derbyia* be classified under combined names: *Orthotetes* for generic designation and *Derbyia* for subgeneric rank.

ECOLOGICAL CONSIDERATIONS

The character of preservation and position of the remains of the Redoak Hollow fauna provide no information that would definitely indicate burial in the original habitat. With the exception of very few specimens of pelecypods (*Nucula subventricosa*, *Nuculana inflata*) and one small brachiopod (*Composita rotunda*), all other bivalves and brachiopods are almost invariably represented only by separated valves. Some of the most fragile shells, such as *Lingula*, *Solen*, and *Sanguinolites*, have valves disconnected but unfractured. Fairly large fragments of the zoaria of species of fragile *Fenestella* are found up to 2 inches long and wide. These facts indicate that even if they were not buried in the original habitat, the remains of the invertebrates in the Redoak Hollow have not been transported far from where they lived. They had lived in waters where the mechanical effect of larger storm waves would account for their being disjointed and partially broken before final burial in the sands.

The whole assemblage of crinoids, bryozoans, calcareous brachiopods, and mollusks is strongly suggestive of the mixed type of marine fauna that is believed to be typically developed at a depth of about 90 to 120 feet in the Pennsylvanian and early Permian seas of the Midcontinent (Elias, 1937). Evidence that part of the bottom where this fauna lived was even shallower is furnished by the finding of a single specimen of a large and nearly unbroken valve of a thin *Lingula* at Locality 1. Further evidence for a shallow part of the sub-littoral bottom of the local sea is found in the abundance of borings of *Cliona* and *Clionolites* in a number of brachiopod and pelecypod shells; it is known that the living boring sponge *Cliona* infests oysters and other pelecypods and gastropods at depths seldom exceeding 100 feet. It seems reasonable to conclude that the described fauna in the Redoak Hollow probably lived at a range of depth not shallower than about 50 or 60 feet and not deeper than 120–140 feet. This depth is somewhat less than that indicated by the facies in the faunas of the Pennsylvanian and early Permian seas of the Midcontinent.

SYSTEMATIC DESCRIPTIONS

FORAMINIFERA

The manner of preservation of the fossils in the Redoak Hollow is not very favorable for detection of the small Foraminifera; only few of them have been observed in the course of the present study. Because they have been found only as incomplete molds, they cannot be assuredly classified and described in the customary manner. Thus, they are mentioned here merely for completeness of the paleontological record, as none is of diagnostic value.

Even though the preservation of Foraminifera of the fauna is not favorable, it seems that their general scarcity in the Redoak Hollow is worthy of notice. The known free Foraminifera of late Mississippian and early Pennsylvanian ages include forms which are not much smaller than the smallest ostracodes which have been found in large numbers in the Redoak Hollow.

The larger invertebrates are generally quite free from adnate Foraminifera. Only two individuals of the latter have been detected; larger shells are not infrequently overgrown by encrusting bryozoans.

AMMOVERTELLA? sp.
Pl. 39, fig. 1

Single small and apparently immature individual, provisionally referred to *Ammovertella*, makes only two volutions around its proloculus. There is some tendency toward triangularity in the outer volution. Form adnate on inner side of dorsal valve of *Diaphragmus fasciculatus* var. *girtyi*, n. var.

TETRATAXIS cf. T. DECURRENS Brady

Very small and fragile mold of *Tetrataxis* comparable to *T. decurrens* in size, angularity of conical conch, and number of its volutions.

PTYCHOCLADIA BASSLERI Elias var. OKLAHOMENSIS, n. var.
Pl. 39, fig. 4a

Ptychocladia bassleri ELIAS, 1950, Jour. Paleont. vol. 24, p. 296; pl. 45, fig. 11,12.

Mold referred to this species was previously classified as a ctenostomatous bryozoan (Ulrich & Bassler, 1904, p. 289–290, pl. 63, fig. 10,13), is found attached to outer surface of fragment of *Chonetes kingi*, n. sp., and in association with *Cliona paleodendrica*, n. sp., which penetrates shell. New encrusting form is discoid, being thus differentiated from genotype *P. agellus* and its varieties, whose growth form is more or less ramose. Dimensions of specimen and spacing of the concentrically arranged narrow embracing chambers approach those in the much better preserved *P. bassleri* from the Kanwaka shale, Shawnee group, Virgil series of the Pennsylvanian at Nehawka, Nebraska. Height of concentric volutions in new var. *oklahomensis* is slightly lower, averaging abt. 05 mm. or 20 per 1 mm., none being higher than .06 mm. In *P. bassleri* from the Shawnee of Nebraska there are about 16 to 18 chambers per mm. along the radius, their height averaging .06 mm., and maximum approaching .1 mm. high.

TEXTULARIA cf. T. GRAHAMENSIS
Cushman & Waters
Pl. 39, fig. 2

Textularia grahamensis, CUSHMAN & WATERS, 1927, Contrib. Cushman Lab. Foram. Res., vol. 3, p. 151, pl. 27, fig. 3a,3b; —— & ——, 1930, Texas Univ. Bull. No. 3019, p. 54, pl. 12, fig. 1a,1b.

Palaeotextularia grahamensis, GALLOWAY & RYNIKER, 1930, Okla. Geol. Survey, Circular 21, p. 21, pl. 4, fig. 13,14.

Single mold comparable to immature *Textularia* of the kind common to the Pennsylvanian of Texas and Oklahoma is a slowly expanding conical form, abt. 3 mm. long and .2 mm. across at the wider end, and consisting of five successive chambers. Specimen from the Redoak Hollow is nearest to the initial part of the conch illustrated by Cushman & Waters from the Gunsight limestone of Texas (1930), though it is nearer in age to the material from the Atoka of Oklahoma described by Galloway & Ryniker. Shell is thick, and chambers about twice as wide as high, as indicated for the initial chambers of the species described by Cushman & Waters.

PORIFERA

Genus CLIONA Grant, 1826

The name of the living boring sponge *Cliona* and of its junior synonym *Vioa* have been occasionally applied to certain organic excavations in fossil shells, including some from the Paleozoic. With the development of a more critical morphologic attitude toward excavations, and since the publication of J. M. Clarke's inspiring studies on "The beginnings of dependent life" (1908), most fossil excavations have been classified in his fossil genus *Clionolithes*, with an understanding that they belong to a boring sponge broadly related to *Cliona*. However, the boring sponge is far from being the only organism that penetrates the shell of various marine invertebrates, and the problem of differentiation between the tunnels produced by boring sponges, boring worms, penetrating ctenostomatous bryozoans, and penetrating algae and fungi is complex. Because students of living boring sponges expressed widely divergent opinions on their nature, metabolism, morphology, and taxonomy, the comparative study of fossil borings progressed slowly and undoubtedly retarded analysis of morphological and anatomical criteria upon which fossil borings could be reasonably assigned. The extensive accounts of living boring sponges, such as those by Hancock (1867) and Topsent (1887), have been generally substantiated by Gray, Carter, and others. Their

work may be put to use by paleontologists in the understanding and classification of fossil excavations in marine invertebrate shells.

Hancock states (1849, p. 321) that "*Cliona* existed during several geological periods, . . . it occurs in the crag, in the London clay, in the Paris Basin, in the chalk, in the greensand, and in the oolite." In present stratigraphic language, these occurrences give the range of *Cliona* throughout the Quaternary, Tertiary, Cretaceous, and Jurassic ages. However, Hancock did not actually describe or illustrate any of the fossil borings which he ascribed to *Cliona*, but limited himself to descriptions of living species only. He described, in all, 24 species of *Cliona* and 2 of *Thoosa*, a closely related genus. Subsequently, M'Coy (1854, p. 260) described some excavations in Paleozoic shells (upper Silurian of the British Isles) under the name *Vioa prisca*. In America, similar and other borings in Paleozoic shells were described by Clarke (1908, p. 168–169, also 1921, p. 87–88) under a new name *Clionolithes;* M'Coy's form was at first included in this genus, but later it was assigned to excavations made by worms (Clarke, 1921, p. 91). The contributions by Clarke, the subsequent work by Fenton & Fenton (1932), but mainly, the exhaustive monograph by Hancock (1849) provide sufficient biologic bases on which borings of *Cliona* and *Clionolithes* can be differentiated morphologically. Other authors have described and illustrated excavations of extant *Cliona* and of fossil *Clionolithes*, but Hancock's investigation of the borings is more extensive and critical than any other published to date. No other author assembled as many examples of Paleozoic borings as Clarke.

Prior to Hancock's work only two species of living *Cliona* were known. He described 24 species of the genus. On the evidence of this material he defines the excavations of the genus thus: "branched; or are composed of lobes united by delicate stems; and all more or less anastomose. . . . They all bury themselves in shells or other calcareous bodies, and communicate with the water by papillae or oscula protruding through circular holes in the surface of the containing substance or matrix" (Hancock, 1849, p. 324). From this diagnosis and from the illustrations of the described species, the genus comprises two kinds of excavations: one is merely branching and anastomosing, and the other is made of "lobes united by delicate stems," and these are also anastomosing. There are also some species of intermediate character that link the two groups. Thus Hancock s concept of the genus *Cliona* includes a great number of species whose types of borings vary considerably, but all are characterized by greater or less anastomosing of the branching excavations. In his genus *Thoosa* the excavations are also of the same type: "branched or lobed, . . . with anastomosing . . ." (1849, p. 345), and this genus is differentiated from *Cliona* only by difference in the character of the spicules, their absence in the interior of the branches, and by the coherence into a surficial crust of the "siliceous bodies" at the surface of the branches. In *Cliona* these surficial bodies are only occasionally connected to form patches of "silicified epithelium" (1849, p. 330). However, Carter (1879, p. 350) expressed doubt on the validity of the genus *Thoosa*, and believed that its supposed different spicules belong to *Samus anonyma*, a non-boring sponge which merely occupied the borings of *Cliona*.

Clarke (1908, p. 168–169; 1921, p. 87–88 briefly described and illustrated four species of his fossil genus *Clionolithes: C. priscus* M'Coy, *C. radicans*, *C. reptans*, and *C. palmatus*. These four species fall into two natural groups: one includes the excavations radiating from a common center, as in *C. radicans* and *C. palmatus*, and the other includes simpler, tube-like excavations which do not have a common center, as in *C. reptans*. Only the excavations of the first group are somewhat similar to the extant *Cliona*, as described by Hancock, the common feature being the radiation of the excavations from a common center. However, these fossil species of *Clionolithes* differ from the species of *Cliona* by the absence of lobations and by the absence of anastomosing in their branches. The excavations of the second group of fossil *Clionolithes* are not only quite unlike any of the species of *Cliona* described by Hancock, but resemble the tube-like penetrations in the fossil shells which are frequently interpreted as the adnate of immerged stolons of ctenostoma-

tous bryozoans, particularly *Condranema* (=part of *Heteronema*, Ulrich & Bassler, 1904, p. 278–279; Condra & Elias, 1944, p. 542–545). Similar tubular borings have been observed in extant marine shells, and were ascribed to the boring sponge *Cliona* (Nassonov, 1883, pl. 18, fig. 6). These borings resemble the fossil structures referred by Clarke to *Clionolithes reptans*, and their reference to *Cliona* is questionable; it has been pointed out that borings by organisms other than *Cliona* can be easily used and enlarged by the latter. If so, the presence of *Cliona* in some borings, not typical for the genus, can be thus explained. Also, fine tubular borings similar to those illustrated by Nassonov (1883, pl. 18, fig. 6), and which occasionally are connected with small elliptical to pear-shaped caves, are believed by Topsent (1887, pl. 4, fig. 1-th) to belong to a "thallophyte perforant," *i.e.*, an alga or fungus. It seems safe to restrict reference to boring sponges only to those fossil excavations which have an undoubted morphological resemblance to the extant excavations which are typical for *Cliona* and *Thoosa*, as described in detail by Hancock. Furthermore, thanks to the analysis of the genus *Clionolithes* by Fenton & Fenton (1932, p. 42–43) it is now possible to restrict the genus and place in it only the radiating fossil borings that resemble undoubted species of extant *Cliona*. Acceptance of this procedure removes from fossil sponges the excavations of doubtful affinity illustrated by Clarke under the names *Clionolithes priscus* and *C. reptans*, as well as *C. priscus* M'Coy (M'Coy, 1854, p. 260, pl. 13, fig. 1–1a) and also the following subsequently described fossil forms: *C. hackberryensis* Thomas (1911, p. 165–166 and plate; Fenton & Fenton, 1924, p. 23, pl. 1, fig. 8; 1932, p. 44–45, pl. 6, fig. 1–2,5–6); *C. canna* Price (1916, p. 688, pl. 25, fig. 1): *C. lizardensis* Lees & Thomas (1918, p. 605–609, pl. 12, fig. 25,26), and *C. irregularis* and *C. fossiger* (Fenton & Fenton, 1932, p. 45–47, pl. 7, fig. 4–7).

Teichert concludes (1945, p. 202) that several names for the borings of this type "are now available" taxonomically: *Clionolithes* Clarke, 1908; *Filuroda* Solle, 1938 (with *Clionolithes reptans* Clarke as genotype); and *Topsentia* Clarke, 1921; and adds his own, Permian genus *Conchotrema* to them ibid., p. 203–208). He does not formulate differences.

The genus *Clionoides* Fenton & Fenton (1932, p. 47) is apparently a junior synonym of *Vinella* Ulrich (1890), no matter what interpretation of these tube-like inclusions in the shells be given. They differ from the known excavations of *Cliona* by the simple cylindrical shape of non-anastomosing branches, which are submerged close to the surface of the shells, and communicate with the exterior by circular perforations arranged in regular rows.

Among the molds of the excavations in the various shells from the Redoak Hollow there are not only the kinds that can be properly classified respectively in *Clionolithes* Clarke in restricted sense, as just discussed, or in *Condranema*, but also the kind that is morphologically indistinguishable from the typical excavations of the extant *Cliona* except being smaller. An attempt to find spicules or siliceous surface epidermis in the fossil borings here referred to *Cliona* proved unsuccessful, and therefore classification with *Cliona* cannot be verified from this point of view. Both kinds of siliceous bodies are so minutely thin in living *Cliona* that if the fossil sponges possessed similar siliceous bodies at all, they would have likely been dissolved subsequent to death of the animal. This would have been particularly likely to happen in the case of the fossils from the Redoak Hollow, where all shell substance, thin or thick, is usually completely dissolved. The organism that excavated the marine shells in Redoak Hollow time has had the same mode of life as extant *Cliona*. Indeed, *Cliona* now bores different genera and species of shells than in Paleozoic time. It is clearly not parasitic in either case as it does not derive organic nourishment from them, but merely uses them as a medium for housing. It is also known to excavate some calcareous rocks just as well.

The only evolutionary tendency that is obvious from a comparison of living and fossil *Cliona* is its considerable progression in size, a tendency common in the evolution of most animals. Such phyletic increase in size, if not accompanied by other morphologic or anatomic changes is usually considered insufficient for generic differentiation.

The species of *Cliona* from the Redoak Hollow include the same extreme morphological diversities within the genus as those observable in its living representatives; that is, they include the forms with constrictions or lobes, such as *C. paleodendrica* and *C. stellata*, and the forms without them, such as *C. fenestralis*.

CLIONA PALEODENDRICA Elias, n. sp.
Pl. 39, fig. 3–10; Pl. 40, fig. 1

This form is comparable to the excavations of the extant species of *Cliona*, as it consists of branches coming out from the common center, each branch usually swelling into lobes, and with the lobes of the neighboring branches anastomosing. Parts of a few branches remain without lobate swellings, especially near their apical or distal portion. The pattern thus composed is a miniature replica of living *Cliona spinosa* or *C. corallinoides* Hancock (1849, p. 339, pl. 13, pl. 15, fig. 1) being about ten to twenty times smaller. Hancock considers width of lobes one of the important characteristics of a species; to this specific character may be added the counting of lobes per given length of a branch as a complementary characteristic. Comparison of *C. spinosa* and *C. paleodendrica* in regard to these two characters is as follows: width of lobes is 2 to 2½ mm. and .1 mm., the number of lobes along a branch 5 per 10 mm., and 5 to 7 per 1 mm. corresponding in *C. spinosa* and *C. paleodendrica*. *C. spinosa* has numerous papillae that arise from the lobes, and similar papillae cover the lobes in *C. paleodendrica;* instead of one to three on each side of a lobe in *C. spinosa* there is a much larger number of papillae covering densely the lobes in *C. paleodendrica*. Another difference is the presence of a considerable thickening of the initial central part in *C. paleodendrica*, a feature neither illustrated nor mentioned in the description of *C. spinosa* by Hancock.

The over-all size of the borings does not seem to exceed 6 mm. across in the plane of its anastomosing branches in *S. paleodendrica*, while it measures about 35 mm. across or more in *S. spinosa* as seen in the sketch by Hancock (1849, pl. 13, fig. 5).

Several specimens of the species have been found in the shells of *Chonetes*, n. sp., and rarely also in the shells of *Spirifer*, n. sp., where individual sponges are usually poorly developed apparently because the sharply plicated nature of the shell prevents normal development of the sponge borings. See illustration Pl. 40, fig. 1.

CLIONA STELLATA Elias, n. sp.
Pl. 39, fig. 11–13; Pl. 43, fig. 6

The individual borings are only .3 to .4 mm. in over-all diameter, each consisting of unequally developed branches radiating from a common center. Each branch consists of very few subcircular swellings spaced not too closely along extremely slender tubes, and the swellings or lobes are very unequal in size. The whole pattern looks like a splash of a drop of milk or other thick liquid with the sprinkles of tiny spherical droplets radiating from the central point of drop's fall. The largest swellings are about .06–.07 mm. in diameter.

The general character of the borings seems to indicate *Cliona*, or a related new genus which would differ from *Cliona* only by the absence of anastomosing of the swellings or lobes. However, such absence of anastomosis may be due to an abbreviated development of the branches of small species, and therefore the species is at the present retained in genus *Cliona*.

The species has been found exclusively in the shell of *Spirifer casteri*, n. sp. It may be merely a juvenile form of *Cliona paleodendrica*, but the following facts seem to indicate that it is an adult form of a diminutive species: the size of its numerous individuals is quite uniform; the individuals are separated from each other by a distance of more than their diameter apart, and thus each individual could have easily developed to a larger size without interference from the growth of its neighbors; furthermore, some immature individuals of *C. paleodendrica* have been found in the same shells where a number of typical *Cliona stellata* borings have also been encountered. They look quite different from those of the latter species and no intermediate forms have been detected. Furthermore, juvenile or individuals of *C. stellata* arrested in their development are occasionally encountered among its adults,

and these consist of very few, from one to four or five unequal subspherical "droplets" or lobes.

CLIONA FENESTRALIS Elias, n. sp.
Pl. 40, fig. 2

The species is erected on a single individual of the boring in a fragment of a shell that seems to belong to a new species and possibly even a new genus of productid brachiopods. The boring is characterized by a perfect radial symmetry of subequal, frequently bifurcating and anastomosing branches, which form a subcircular expanse 5 mm. in diameter. The width of the branches varies but little, averaging .1 mm., but reaching .2 mm. or slightly more. The loops of the network formed by the frequent anastomosing vary from .1 mm. to .8 mm. in length, and from .1 mm. to .5 mm. in width. The branches do not seem to have a tendency to become constricted, in which character the form differs from all extant species of *Cliona* illustrated by Hancock. However, he describes two species of extant *Cliona: C. muscoides* (1849, p. 335) and *C. labirinthica* (1849, p. 345), whose branches are said to be devoid of any lobes or constrictions indicative of lobes, and these species, thefore, are apparently comparable to *Cliona fenestralis*. *C. muscoides* seems particularly like *C. fenestralis* as it is said to have "numerous delicate, much-divided, closely and irregularly anatomosing branching . . . the principal branches about 1/16th of an inch thick, and distinctly seen ramifying throughout the general interlacement of the sponge" (Hancock, 1849, p. 335). *C. fenestralis* differs from it, however, in having more delicate branches as well as presumably much smaller over-all size. Thus the fossil form belongs to the small group of *Cliona* species whose branches do not swell into lobes, but anastomose more or less frequently and thus build a distinct network.

Genus CLIONOLITHES Clarke, 1908

As discussed under the heading *Cliona* genus *Clionolithes* is restricted to the species with radiating branches only, and only two among the previously described species are retained in it: *C. radicans*, and *C. palmatus*. The genus differs from *Cliona* by the absence of swellings or constrictions in the branches and by the absence of anastomosis.

Type species: *Clionolithes radicans* Clarke (subsequent designation, Fenton & Fenton, 1932).

CLIONOLITHES cf. C. RADICANS Clarke
Pl. 40, fig. 3

Clionolithes radicans CLARKE, 1908, N. Y. State Mus., Bull. 121, p. 168; pl. 9, fig. 2; pl. 10; pl. 11, fig. 1,2; ——, 1921, *Ibid.* Bull., 221–222, p. 88, text-fig. 70–72; FENTON & FENTON, 1932, Midland Naturalist, vol. 13, p. 43.

A few borings have been encountered in *Spirifer casteri* which approach *C. radicans* Clarke in the absence of swellings and of anastomosis. Clarke illustrated a number of examples of *C. radicans* in the brachiopods *Dalmanella superstates*, *Atrypa reticularis*, and *Leptostrophia magnifica* from the Devonian of New York and Pennsylvania (Clarke, 1908; pl. 9, fig. 2; pl. 10; pl. 11, fig. 1,2); and he believed the form restricted to the Devonian. The form from the Redoak Hollow seems to have a slight tendency to develop swelling in its branches, and thus differs from *C. radicans* in this respect.

CRINOIDEA

Remains of crinoids are fairly common in the Redoak Hollow. Not a single crown or cup has been discovered, and the remains consist of isolated columnals of stems and arms, and occasionally plates and other parts of cups. The remains are generally not identifiable even generically; at present, the taxonomy of the Flexibilia, where these remains probably belong, is based exclusively on crowns or calyces; but not isolated plates. There seems to be no serious reason why the isolated plates and segments of crowns and stems should not be eventually used in stratigraphic paleontology, even if their assignment to definite genera and species, as now differentiated, cannot be attained. The problem is merely that of organization of these remains in some manner that is useful stratigraphically. Twenty years ago, R. C. Moore made a heroic attempt at an utilitarian classification of "fragmentary crinoidal remains" (1939) and introduced a special kind of binomial

nomenclature similar to Linnean nomenclature but not a part of the present Rules of Zoological Nomenclature. In this attempt he follows and develops Croneis's idea or "Utilitarian classification of fragmentary fossils" (1938). It seems inadvisable to follow this classification. In addition, the coined names in the "utilitarian classification" are long and cumbersome, constituting an unnecessary burden for the already overly burdened paleontological nomenclature. Instead, an attempt is made here to assign provisionally the fragmentary remains from the Redoak Hollow to the crinoidal genera legally recognized in the Mississippian and Pennsylvanian strata of America and in the rest of the world. Their relation to the genera under question mark indicates only possibility, while the reason for such tentative reference is explained in an accompanying descriptive text. The tentatively indicated generic (and occasionally even specific) names are used as mere taxonomic "handles" for the fragmentary remains, and, as classification of these remains will be developed as time goes on, such assignments will be verified, changed, or otherwise improved. A great deal more can be learned about taxonomic affiliation of fragmentary crinoidal remains from their morphology and anatomy, than is practiced at the present. For instance, the sculpture of crowns and stems, which is usually only casually mentioned, should be studied in greater detail and be considered in generic and specific identifications. Taxonomic importance of external sculpture has been already firmly established for brachiopods, ammonites, nautiloid cephalopods, pelecypods, gastropods, and other invertebrates, and there seems to be no serious reason not to recognize its importance in taxonomy of the fossil crinoids. Perhaps of even greater potential importance in their taxonomy are microstructure of the skeletal parts, whose study at the present has barely begun. However, harmonious study of both sculpture and anatomy should begin with the more completely known crinoidal remains, particularly those consisting of both crown and stem, and then be gradually extended to less complete remains. This is indeed a long range project, and in the meantime the fragmentary remains may be merely recorded, with particular emphasis on details which seem to be of eventual use in taxonomy and stratigraphy. Following is such record for the fossils from the Redoak Hollow.

Not all recovered fragmental crinoidal remains are being recorded even under questionable generic names, but all of them that have any distinctive features, with the exception of the most common and featureless cylinder shaped with circular-lumen "Indian beads," are here illustrated.

The most attentive search among these remains failed to discover the "helm" type of crinoidal columnals that have a set of irregularly spaced and diverse lateral spines, and are highly characteristic of the Chester series and down to the Keokuk in Illinois and its equivalent in the subsurface of south-central Kansas and adjacent part of Oklahoma (personal record based on surface and subsurface samples correspondingly). Neither does the present material from the Redoak Hollow contain any columnals with *regularly* distributed lateral pimples or short spines, such as has been collected from the upper Morrow (Otterville to Lester) from near Ardmore (personal material collected in 1947).

Order INADUNATA Wachsmuth & Springer
Suborder FISTULATA Wachsmuth & Springer
Family BOTRYOCRINIDAE Bather

Barycrinus? aff. *B. herculeus* Meek & Worthen

Pl. 41, fig. 1,2

The single external mold of a part of a stem containing a set of 14 columnals is questionably referred to the genus on the evidence of the peculiar regularity of the succession of the joints which have variable diameter. Each fourth joint has convex sides and larger height and diameter; and the middle one of the three joint sets in-between also possesses convex sides, and is higher and of slightly larger diameter than the other two, which have flat or nearly flat lateral sides. The diameter of the largest segments is 4 mm. and the height is 1 mm. The diameter of the smallest segments is 3 mm. and the height is about .5 mm.

It seems that the nearest columnal among the published Carboniferous crinoids is that

of *Barycrinus herculeum* (Meek & Worthen, 1873, p. 485–486, pl. 13, fig. 2a). Judging by the published sketches of the attached columnals the diameter of its largest segments is 11 mm., and their height is about 1.5 mm.; the diameter of the smallest segments is 10 mm., and the height averages about .75 mm.

Family CYATHOCRINITIDAE Bassler
DELOCRINUS cf. D. DUBIUS Mather
Pl. 41, fig. 3

External mold of a fragment of a single plate possesses a beautifully preserved shagreen, the pattern of which seems sufficiently characteristic for generic and perhaps even specific identification. The pattern of shagreen is made of short undulating ridges, which are divided by narrow valleys and frequently tend to break down into isolated hills. There is a slight tendency of the "grain" of the shagreen near the edges of the plate to be perpendicular to them. There are several forms in the upper Morrow that have the shagreen of the calix approaching that in the described fragment. Moore & Plummer (1938) published their photographs which show various shagreens better than in the previous publications, and among these the shagreen of *Paradelocrinus dubius* (1938, pl. 13, fig. 2a–c), *Delocrinus matheri* (1938, pl. 13, fig. 3; pl. 16, fig. 1a–c), *Hydriocrinus? rosei* (1938, pl. 14, fig. 8a–d; pl. 16, fig. 9), *Morrowcrinus fosteri* (1938, pl. 13, fig. 4a–d; pl. 16, fig. 11), and *Ethelocrinus hispidus* (1938, pl. 15, fig. 4a–d) have the mentioned comparable type of shagreen. By a closer scrutiny of the listed illustrations of the shagreen, that of *Paradelocrinus dubius* seem the nearest to that in the described fragment. Furthermore the curving of the surface of the fragmentary plate is very close to the same in the basal part of the radial plates (RR) illustrated by Moore & Plummer (1938, pl. 13, fig. 2a, compare upper central part of the illustration).

The described fragmentary plate is referred to genus *Delocrinus* rather than to *Paradelocrinus* because the latter is differentiated from the former only by "lacking an anal plate as an element below the upper edge of the cup" (Moore & Plummer, 1938, p. 294)—a feature that can be observed only when the whole cup is preserved. Perhaps *Paradelocrinus* should be ranked rather a subgenus of *Delocrinus*, if not a mere mutation of the latter.

Delocrinus has not been found as yet in the Mississippian rocks of America and is an exclusive Pennsylvanian and Permian genus.

ETHELOCRINUS? KIRKI Elias, n. sp.
Pl. 41, fig. 4,5

External molds of two fragmentary plates and one of infrabasal are questionably referred to this genus on the evidence of the shape of the infrabasal, and the peculiar roughly designed sculpture, which consists of closely set irregularly and variably outlined truncated ridges which are separated by narrow, vermiform, trench-like valleys. It seems that among all crowns and calyces previously illustrated in the literature of Carboniferous crinoids only the external surface of the crowns in *Ethelocrinus hispidus* (Moore & Plummer, 1938, pl. 15, fig. 4a,4c) and in *Ethelocrinus papulosus* (ibid., 1930, p. 15, fig. 5a,5e) is more or less comparable to that in the described species, while the depressed infrabasal and the surface of the attachment of the stem in one Redoak Hollow specimen seems to support this generic assignment. Reference of one collected infrabasal to the same genus and species with the two mentioned fragmentary plates is based on the similarity of their sculpture. However, because this sculpture is not exactly the same as in the above mentioned two species of *Ethelocrinus*, the form from the Redoak Hollow represented by all these fragments is differentiated as a new species, and only questionably referred to genus *Ethelocrinus*.

Ethelocrinus is an exclusively Pennsylvanian genus.

Family PALECOCRINIDAE Kirk
PALECOCRINUS? sp.
Pl. 41, fig. 6,7

Several columnals have been recovered that have circular outline, pentamerous petaloid lumen, and straight lateral sides. Similar columnals from the Wewoka formation (=Upper Marmaton group of Des Moines series) of Oklahoma are illustrated by Girty (1915) who classifies them in two

groups, *A* and *B*. In group *A* he places the round columnals with straight sides and in group *B* the round columnals with convex sides. In useful compilation set of some Silurian, Devonian, Mississippian, Pennsylvanian, and Mesozoic-Recent columnals published by Moore (1939, fig. 5, on p. 188) all Mississippian round columnals with pentagonal lumen have their articular surfaces evenly flat, that is without central depression (ibid., fig. 5–6.17,18,19,21,22,23), while the two illustrated Pennsylvanian columnals of the same general type are centrally depressed (ibid., fig. 5–16b,24). The latter columnals are redrawn from the photographs published by Girty, who illustrated four columnals, all with central depressions (Girty, 1915, pl. 3, fig. 3,4,5 and 8).

It seems probable that these columnals from the Wewoka evolved from those in the Redoak Hollow by the development of the depression. If so, an intermediate type of columnal with petaloid lumena are likely to be found in the Springer, Morrow, and Atoka series. Unfortunately no columnals have been described in the papers on the crinoids from the upper Morrow by Mather (1915) or Moore (1939), although some of the forms known from there possess pentagonal lumen in the stem.

The discussed columnals from the Redoak Hollow are questionably classified with genus *Palecocrinus* Kirk, the columnals of which are pentagonal in transverse outline in the proximal part of stem, but becoming circular in the distal part of it (Kirk, 1941, p. 82–83).

Order ADUNATA Bather
Family PLATYCRINITIDAE Bassler
(Platycrinidae Roemer)
PLATYCRINITES? sp.
Pl. 4, fig. 8–10

There are a number of diversified fragmental pieces which are generally as high as wide, and drum to barrel shaped. They are ornamented with spine-like projections, which are adpressed to the sides so that their apices point toward one of the flat articular ends of the drum or barrel. In view of their circular transverse outline and considerable height, which is about as large as or larger than width, these pieces are likely to be segments of cirri, but at the present none are known that would be ornamented in this fashion. Some species of *Platycrinites* have arms which possess nodes pointing slightly proximad (see Meek & Worthen, 1873, pl. 3, fig. 4d,5b,6b). Perhaps the cirri of some species of *Platycrinites* could have the kind of sculpture similar to that in their arms; reference of these cirri to *Platycrinites* is entirely speculative.

Family HEXACRINITIDAE Bassler
(Hexacrinidae Wachsmuth & Springer)
PTEROTOCRINUS? SPRINGERENSIS Elias
n.sp.
Pl. 41, fig. 11

The Mississippian genus *Pterotocrinus* was comprehensively reviewed by Sutton (1934), who also demonstrated its considerable stratigraphic usefulness in differentiating the subdivisions of the Chester series into formations. The most specifically characteristic parts of the crowns in this genus are the "wing plates," that occur in sets of five, each spaced in-between the bases of the arms. A single wing plate which apparently belongs to this genus has been recovered from locality No. 1 of the Redoak Hollow. Its calcium carbonate was practically dissolved but the plate did not disintegrate, as its lattice of tiny canals was filled with limonite possessing sufficient coherence for its preservation.

The plate is generally as flat as most of the typical wing-plates of *Pterotocrinus*, and is bilaterally symmetrical about a plane perpendicular to its flatness. When following Sutton's morphology and terminology for the wing plates of *Pterotocrinus* one can recognize in the form from the Redoak Hollow a basal part which expands rapidly into a blade that is wider than high. The outline of the blade in the present form is, perhaps, the most complex among all previously described species of the genus. It has on each side wide and slightly bilobate lateral expansions, and also a wider medial expansion with two lobes, but more strongly differentiated and more widely divergent than the lobes in the lateral expansions. On one side of the wing-plate and close above its base is a semi-lunar depression which seems to be a ligamental pit to connect it with an

underlying radial plate (similar depression is illustrated, though not described by Moore, 1939, text fig. 2–27 on a "facetal" from the Burlington). The position of this depression in the plate of bilateral symmetry suggests an orientation of the five wing plates in a plane perpendicular to the axis of the crown, somewhat like the wing plates of *Pterotocrinus bifurcatus* Wetherby or of *P. coronarius* (Lyon) (see Sutton, 1934, pl. 50, fig. 16,27).

In spite of the complexity of the outline the wing plate of *P.? springerensis* is comparatively small: 7 mm. wide and 4.5 mm. high, smaller than all the plates of the stratigraphically highest among the previously known species: *P. menardensis* Weller from the Menard, and *P. clorensis* Sutton from the Clore (Sutton, 1934, pl. 49, fig. 47–49, 52,53).

Sutton records, but does not describe in detail or illustrate large "wing plates" similar to those of *P. clorensis* and *P. menardensis* from the Kinkaid limestone of western Kentucky, which "shows the continuation of the *P. depressus* line of development to the end of the Mississippian period" (Sutton, 1934, p. 406). The new species *P.? springerensis* can hardly belong in the phyletic series of *P. depressus*, as its wing-plates are apparently oriented perpendicular to the crinoidal axis, or are horizontal, while the wing-plates in *P. depressus* are oriented in vertical radiating planes. In view of this, and because there is no proof that the plate from the Redoak Hollow belongs to *Pterotocrinus*, it is placed in this genus tentatively.

ECHINOIDEA

PHOLIDOCIDARIS? cf. P. IRREGULARIS Meek & Worthen

Pl. 41, fig. 12–15

Pholidociearis irregularis, MEEK & WORTHEN, 1873, Ill. Geol. Survey, vol. 5, Paleontology, p. 512–513, pl. 15, fig. 9a–c (fig. 9a misprinted as 4c on the plate).

Only isolated Echinoid spines, larger and smaller, have been recovered, also a very few fragmentary plates of the "collar-button" type. These isolated remains are generally insufficient for even generic identification, because different genera occasionally bear similarly developed spines and some of their plates also are similar. Not only external but also complex internal structure of the spines from the Redoak Hollow is preserved in all details, and perhaps in the future, when the anatomy of the spines will be studied systematically such well preserved remains will be possible to classify with assurance. As this is not the case, the remains from the Redoak Hollow are here questionably referred to *Pholidocidaris*, an upper Mississippian genus whose spines are simple cylindrical, very gradually tapering bodies, with fine longitudinal striation, and slightly expanded door-knob shaped base. Some larger primary spines and smaller secondary spines of *Pholidocidaris* have about the same shape, and the spines in the Redoak Hollow are of the same two kinds, and have the same mutual proportional magnitude.

There is a group of species of *Archaeocidaris* from the lower Carboniferous of America and Europe, typified by *A. wortheni* Hall, whose spines are generally similar to those of *P. irregularis* in that they are slender and bear no barbs. They differ in being invariably smooth, and in most cases inflated (Jackson, 1912, pl. 9, fig. 9–13; and pl. 10, fig. 1–9). *Archaeocidaris halliana* Geinitz from the Upper Pennsylvanian at Nebraska City, Nebraska has similar slender spines that are not smooth, but appear longitudinally striated. However, when seen under magnification their surface appears ornamented "with minute spinules in numerous vertical series" (Jackson, 1912, explanation to pl. 15, fig. 4). Spines more nearly identical to those of *Pholidocidaris* are encountered in some of the species of *Lepidocidaris* (Jackson, 1912, pl. 16,17); in fact the spines from the Redoak Hollow could be easily assigned to this genus with as much justification as to genus *Pholidocidaris*. Such alternate identification would not change its stratigraphic significance, because both *Pholidocidaris* and *Lepidocidaris* are characteristic Mississippian genera.

ANNELIDA

SPIRORBIS ELEGANS Elias, n.sp.

Pl. 40, fig. 4

The single specimen consists of two and a half or three coils, the outer two coils sculptured on their upper surface by very

oblique angular ribs of varying intensity. Its few stronger, almost spine-like ribs are more or less regularly spaced (about six per volution) among the more numerous, weak to moderately prominent, and less oblique costae (lines of growth?). The shell is nearly 2 mm. in diameter, and the end diameter of its last volution is ¾ mm.

Discussion.—The small form is so regularly coiled that it could be with almost equal propriety compared with coiled cephalopods or planispiral gastropods. The irregular distribution of the stronger among the numerous ribs, which are all oblique in relation to the axis of coiling, and the very small size of shell make its classification with *Spirorbis* most probable. None of the previously known ammonoids from the late Paleozoic have sculpture as oblique and irregular as that in the Redoak Hollow form; also coils of such small early ammonoid volutions are usually evolute or only slightly involute while the coiling in the new form is strongly involute.

It seems that none of the known late Paleozoic planispiral gastropods are ornamented with coarse oblique structures similar to the Redoak Hollow form, but several genera of Ordovician and Cambrian gastropods have similar sculpture, all of them being much larger forms. At least two species of late Paleozoic *Spirorbis*, *S. nodulosus* Hall from the St. Louis limestone of Indiana and *S. anthracosia* Whitfield from the "Coal Measures" of Ohio have similar oblique orientation of variable sculpture as in *S. elegans*, though neither is exactly like it.

The shell is half the size of *Spirorbis annulatus nodulosus* and could be considered an immature individual of this species (Hall, 1856, p. 34; Beede, 1906, p. 1272, pl. 26, fig. 31), if it were not that the sculpture of the upper side of the latter consists not only of the oblique ribs, but also of one spiral elevation along the middle of the upper side of the volutions. The sculpture of the outermost volution in *S. nodulosus* is further complicated by the development of several concentric rows of regularly spaced and prominent nodes. Thus, *Spirorbis elegans* has somewhat simpler structure in comparison with *S. nodulosus*, and its spine-like elevations on the strongest oblique ribs make only a single row, as they are lined up closer to the center than to the outer edge of the volution.

Spirorbis anthracosia Whitfield is about the same size ("one line") and approaches *S. elegans* closely in the variability of the sculpture of its shell, but its ribs and lines of growth are not as oblique as in *S. elegans*, and the number of the coarsest elevations which are lined up near the umbilicus is much larger, up to 16 per volution, than the number of spine-like elevations in *S. elegans* which is only 6 or 7 per volution. Furthermore, the coiling in *S. anthracosia* is not planispiral, but rather high-spired, and more evolute than involute, with a wide and deep umbilicus.

Cornulites inelegans Hyde
Pl. 40, fig. 5,6

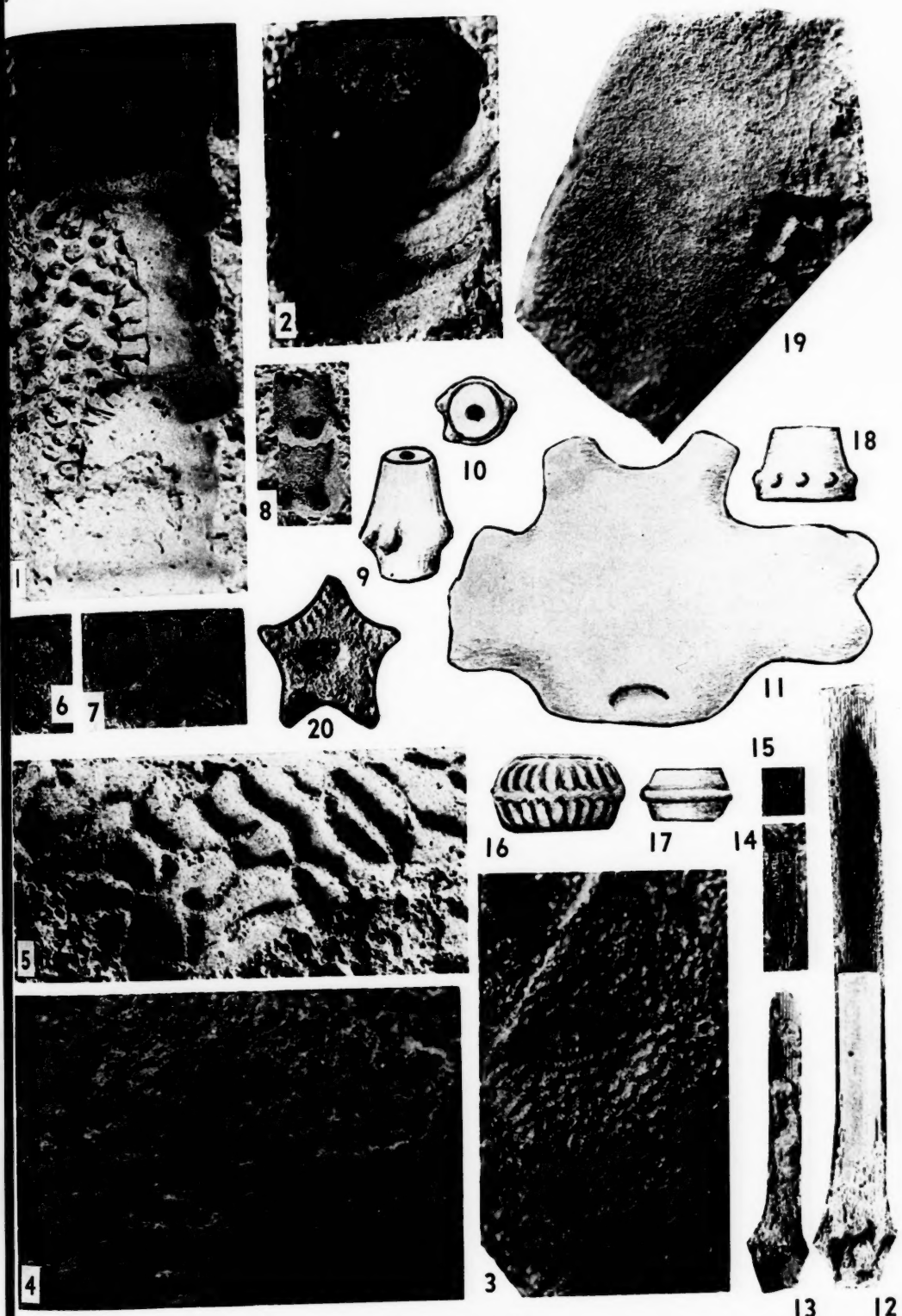
Cornulites inelegans Hyde, 1953, Ohio Geol Surv. Bull. 51, p. 290; pl. 53, fig. 9.

The single specimen in the Redoak Hollow is shorter than *Cornulites inelegans* from the Logan formation (lower Mississippian) of Ohio, but is identical with it in all other respects.

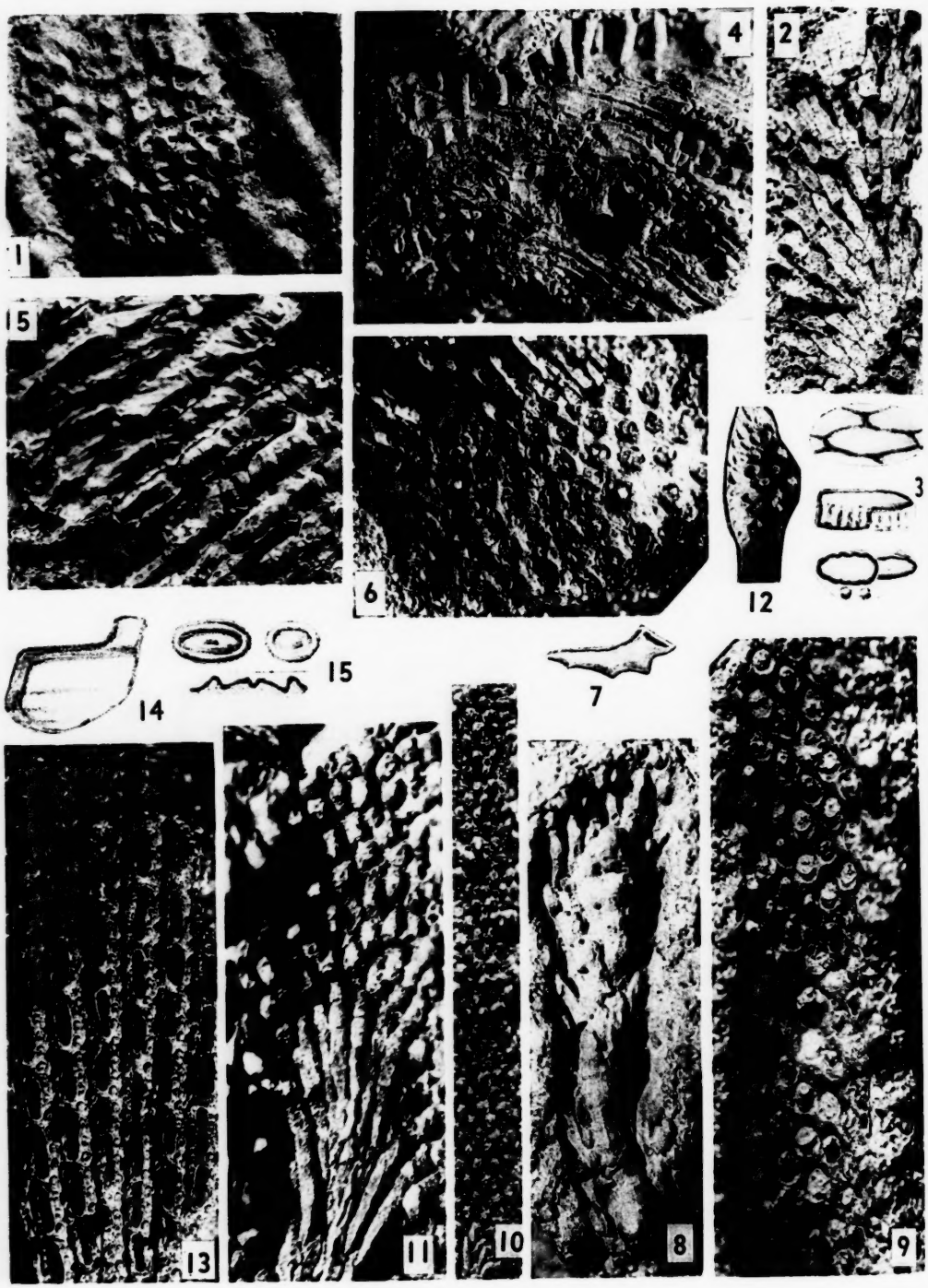
The shell is a slowly expanding and not quite straight cone. It is about 3½ to 4 mm.

Explanation of Plate 41

Fig. *1,2*—External mold of part of stem of *Barycrinus*? aff. *B. herculeus* Meek & Worthen, encrusted by *Eridopora* (*Discotrypella*) *radiata*, n. sp., ×10.
3—*Delocrinus* cf. *D. dubius* Mather. External mold of a plate, ×10.
4,5—*Ethelocrinus*? *kirki*, n. sp. External molds of two plates, ×10.
6,7—*Palecocrinus*? sp. External molds of columnals, ×1.
8–10—*Platycrinites*? sp. *8*, External mold of two adjacent cirri.
11—*Pterotocrinus*? *springerensis*, n. sp.; ×10.
12–15—*Pholidocidaris*? cf. *P. irregularis* Meek & Worthen. *12,13*, molds of a primary spine, *14,15*, molds of secondary spine; cross-section and longitudinal section, ×10.
16–18—Columnals of unknown crinoids; ×10.
19,20—Molds of infrabasal plate and of a columnal of undetermined crinoid, ×10.



Maxim K. Elias



Maxim K. Elias

long and 1½ mm. in diameter at its distal end. Its surface is roughly annulated, the width of the annulations increasing from ½ mm. in the proximal part to ½ mm. in the distal part of the shell. Some of the annulations are complicated by a locally developed, subcentral short and sharp groove. The whole surface of the shell is covered by fine lines of growth. There are a few faint longitudinal ribs occasionally developed in the depressions between the annulations.

The internal mold shows the same number of annulations as the external mold of the shell, but they are shaped somewhat differently, as each ring is nearly flat and with a distinct distal overlap. A very distinct scar of attachment, in the form of flattening of the surface, is reflected in the inner mold for a distance of about 1 mm. from the proximal end of the shell (pl. 2, fig. 5).

Discussion.—*Cornulites inelegans* differs from all known species of this genus by its much smaller size and insignificant or practically absent longitudinal ribs. Silurian *Cornulites arcuatus* Conrad is most similar to it in the character of sculpture, but is a much larger (20 mm. long) shell.

The occurrence of *Cornulites inelegans* in the Redoak Hollow lengthens its previously known range. The genus has not been found higher than the Mississippian.

PENETRANTS OF UNCERTAIN AFFINITY

This heading is proposed for small organisms (few microns to few millimeters) capable of producing excavations, mostly in shells of marine invertebrates. Such excavations are known to be produced by algae, sponges, ctenostomatous bryozoans, worms, minute cirripeds, and others. Because it is not the organism itself but its excavation that is the subject of paleontologic record, and some excavations can be only doubtfully ascribed to a definite organism, it is convenient to describe them together. In doing so it is possible to bring out the morphologic distinctions that allow differentiation of one type of excavation from another.

Genus BASCOMELLA Morningstar

This genus was proposed by Morningstar (1922) for a zoarium-like combination of egg-shaped vesicles and tubular stolons, in a supposed interconnection. Condra & Elias (1944, p. 538,539) examined Morningstar's original material from the Pottsville of Ohio, and re-described and re-illustrated it in connection with the study of their own extensive material on similar excavations from the Upper Pennsylvanian and lower Permian of the northern Midcontinent. Although they regarded the assumed rela-

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EXPLANATION OF PLATE 42

FIG. *1*—*Eridopora* (*Discotrypella*) *stellata*, n. subgen., n. sp., ×10. Holotype, on *Dictyoclostus americanus*, basal Eskeridge shale, Lower Permian, Roca, Nebraska.

2—*Sterbloplax crustacea*, n. gen., n. sp., bottom view of internal mold: ×10.

3—*Strebloplax crustacea*, n. gen., n. sp. Top, side, and bottom views of an internal mold of zooecial chamber, ×30. Bottom view of a part of zoarium, ×30.

4–7—*Eridopora* (*Discotrypella*) *radiata*, n. sugben., n. sp., ×10. *4*, outer mold of a base with concentric wrinkles, marginal zooecial tubes, and a few rows of rudimentary zooecia along some of the wrinkles. *5*, Basal view of a part of discoid colony. *6*, Outer mold of a base with concentric wrinkles. The additional set of coarser and parallel wrinkles, that are superposed diagonally, are caused by the attachment of the colony to the reverse of *Fenestella*, whose branches are thus reflected. *7*, Mold of individual zooecium; side view; ×25.

8–9—*Cheilotrypa distans*, n. sp., ×10. *8*, Longitudinal section showing the irregularly contracting and expanding inner core, and the zooecial tubes inclined about 45° to the surface. *9*, Outer mold showing longitudinally and diagonally disposed apertures, from some of which are extended zooecia, that contract slightly and gradually downwards.

10—*Rhabdomeson* (*Rhombopora*) *ulrichi*, n. sp. Outer mold with some tubular zooecia attached to the apertures, especially at the bottom, ×10.

11—*Tabulipora macnairi*, n. sp. Holotype. Internal longitudinal view, showing thinner, initial parts of the zooecial tubes in the axial portion of the zoarium, and the wider, mature parts of the zooecial tubes, traversed by diaphragms, in the cortical portion of the zoarium, ×10.

12—*Tabulipora*? sp. Small zoarium attached to crinoidal stem, ×10.

13–15—*Fenestella exigua* var. *springerensis*, n. var. *13*, Outer mold of obvsere, ×10. *14,15*, views and profile of apertures and operculum, ×60; and lateral view of internal mold of zooecial chamber, ×30.

tionship of *Bascomella* to ctenostomatous bryozoans "with doubt" and only "provisional," they continued to apply the name *Bascomella* to the *combination* of "stolons" and "vesicles," though pointing out the occasional occurrences of the two structures separately.

In 1956, when in America, Dr. Alfred Seilacher, professor of geology at Tübingen University, Germany, informed me of his impression that the "vesicles" of *Bascomella* bear a striking resemblance to the excavations of the living miniature barnacle *Alcippe* (Hancock, 1849), and are likely to be produced by a similar fossil organism. Dr. Seilacher kindly permitted me to publish his remark, and I agree with him that an *Alcippe*-like barnacle rather than ctenostomatous bryozoan has probably produced the egg-shaped *Bascomella* excavations; if so, however, their combination with the stolon-like excavations is accidental. The fact that the latter occasionally run into the egg-shaped excavations merely indicates their independent and non-contemporaneous origin.

Indeed, Morningstar's specific name *gigantea* for the original *Bascomella* implied correctly that its size is much larger than that of the known ctenostomatous bryozoans and, as we now realize, it is quite within the magnitude of the living minute barnacles. The shape and orientation of the excavations are also quite comparable to those of the living *Alcippe*, as will be discussed.

In view of all this, it is here proposed that the generic name *Bascomella* be applied to the egg-shaped excavations, and not to their combination with stolon-like excavations which are only occasionally found with them. Hence the generic diagnosis for *Bascomella* must be correspondingly abbreviated and modified from that given by Condra & Elias (1944, p. 538) thus: Oval to pear shaped excavations, narrower end closer to surface of host shell; occurring singly or in irregular groups.

The suggestions for *Bascomella* may be compared with subdivision of a previously established genus into two genera in which one is to retain the old name. However,the application of the name *Bascomella* to one of the original combination is restricted to the vesicle alone because the other, the stolon-like part, when considered by itself, is indistinguishable from *Condranema* Bassler, 1952 [previously a part of *Heteronema* Ulrich & Bassler, not *Heteronema* Dujardin, 1841].

BASCOMELLA cf. B. GIGANTEA Morningstar
Pl. 40, fig. 7,8

Bascomella gigantea MORNINGSTAR, 1922, [part] Ohio Geol. Surv. Bull. 25, p. 157–158; pl. 6, fig. 18–20. *Bascomella gigantea* CONDRA & ELIAS, 1944, [part] Geol. Soc. Amer. Bull. vol. 55, p. 539–541; pl. 6, fig. 20–22; pl. 9, fig. 3–5,7,8; pl. 10, fig. 4–11; pl. 11, fig. 1–6.

The specimens which are here recorded as *Bascomella* cf. *gigantea* are groups of obovate vesicles, not associated with any stolons, and probably produced by a miniature barnacle. They differ from somewhat similar molds of *Seminolithes clarkei*, n.sp., by their more or less obovate shape, one end being always more acuminate than the other. Although the shape of *Seminolithes* is also somewhat obovate, it assumes this contour only in the plane of flattening, thus resembling pumpkin seed.

Genus SEMINOLITHES Hyde

Seminolithes HYDE, 1953, State of Ohio Div. of Geol. Surv., Bull. 51, p. 215.

Type species: *Seminolithes linii* Hyde.

The genus is erected "for the fillings of cavities in shells made by a boring organism . . . , which are lenticular in shape." The only species, *Seminolithes linii* is described as "thin lenticular cavities, elliptical in outline and usually standing either normal to the surface of the shell or inclined to it, rarely lying nearly parallel to the surface. Occasionally the surface of the filling of such a boring has the appearance of having had very fine thread wound around it. The general shape and size, although variable, are comparable to those of flax seed."

Discussion.—Hyde does not compare his genus with previously known fossil excavations. *Seminolithes* resembles *Caulostrepsis* Clarke and *Bascomella* Morningstar (em. Elias), its shape similar to the former while its orientation to the host-shell is like that in the latter. *Bascomella fusiformis* Condra & Elias (1944, p. 541; pl. 10, fig. 12–14) is about the size of *S. linii*. However, it is

somewhat longer and perfectly fusiform without flattening of its sides.

A good number of the fillings of the excavations in the shells from the Redoak Hollow are more similar to *Seminolithes* than to either *Caulostrepsis* or *Bascomella*.

SEMINOLITHES CLARKEI Elias, n.sp.
Pl. 40, fig. 10,11

This new species is found in the shells of the brachiopods *Buxtonia semicircularis* (Sutton & Wagner), *Spirifer casteri*, n.sp., and a fragment of another, undetermined large brachiopod in which it is particularly prolific; the latter is selected as holotype of the species (pl. 2. fig. 11).

The fillings of the borings are obovate but with a distinctive flattening on the lateral sides that are perpendicular to the surface of the host-shell. This flattening distinguishes them from the obovate casts of *Bascomella gigantea* but does not make them as thin as casts of *Seminolithes linii* Hyde. Table 2 shows comparative dimensions for the four discussed species of *Bascomella* and *Seminolithes*.

TABLE 2

Genus and Species	Width	Length	Age
Bascomella gigantes Morningstar	.8–.9	1.6–2.0	Pottsville to L. Permian
Bascomella fusiformis Condra & Elias	.3–.4	1.5	Douglas gr., U. Pennsylvanian
Seminolithes linii Hyde	.3–.5	2.0	Logan fm., Osage series
Seminolithes clarkei Elias, n. sp.	.6	1.2	Redoak Hollow, U. Chester

Genus CONDRANEMA Bassler

Heteronema ULRICH & BASSLER, 1904 [part], Smiths. Misc. Coll., vol. 45, p. 278, pl. 65. BASSLER, 1911 [part], U. S. Nat. Mus. Bull. 77, p. 57, text-fig. 6a–d. BASSLER, 1922 [part], Smiths. Inst. Ann. Rep. for 1920, p. 355, text-fig. 6-1,2. CONDRA & ELIAS, 1944 [part], Geol. Soc. Amer. Bull. vol. 55, p. 542–545; pl. 6, fig. 19; pl. 7, fig. 4–6; pl. 8, fig. 5–8.
Condranema BASSLER, 1952, Jour. Wash. Acad. Sci. vol. 42, p. 381.

Simple, straight to curved cylindrical tunnels in fossil shells, interpreted as creeping stolons of stoloniferous Ctenostoma. They are immersed in various shells as deep as their own diameter only, so as to allow supposed attachment of the upright membranaceous polypides to their upper surface. The latter requirement results in the most characteristic feature of the genus—a close proximity to the surface of the shell of the immersed stolons, and occurrence along the outer side of the stolons of sporadic or regularly spaced slightly elevated circular scars of attachment of the zooecia.

Discussion.—Presence of zooecial scars distinguishes *Condranema* from the cylindrical tunnels produced by other animals or plants, which also penetrate shells, and in doing so, need not keep close to their surface. Only the tunnels of the boring sponge *Cliona* are habitually connected with the outside by a series of short perforations spaced along the linear tunnels, as are the stolons of ctenostomatous bryozoans. Only a few species of *Cliona* have linear tunnels without rhythmic constrictions, but they invariably radiate from a common center, and occasionally anastomose, whereas neither of these features is typical for *Condranema*.

Genotype of *Condranema* is *Heteronema capillare* Ulrich & Bassler from the Silurian of Gotland Isle.

The Devonian *Filuroda* Solle (1938) differs from *Condranema* in that its "vermiform tubes . . . wander loosely and at random" and their diameter attenuates repeatedly (see *Clionolithes reptans*, genotype of *Filuroda*, in Clarke, 1908, p. 168; pl. 11, fig. 3). The Permian *Conchotrema* Teichert (1915, p. 203) is like *Filuroda* but with straighter tubes.

CONDRANEMA cf. C. MAGNA
(Condra & Elias)
Pl. 40, fig. 9

Heteronema magna, CONDRA & ELIAS, 1944, Geol. Soc. Amer. Bull. vol. 55, p. 543–545, pl. 7, fig. 4–6.

To this species may be referred some stoloniferous systems immersed in the shells of bivalves close to their outer surfaces, as the stolons in some valves of *Acanthopecten grandis*, n.sp., and others. These stolonifer-

ous systems differ from *Marcusodictyon priscum* var. *vinei* only in that they do not form angular loops, as the stolons in both kinds are of the same thickness and have the same bulbous lateral outgrowths.

BRYOZOA

Order CTENOSTOMATA

Genus MARCUSODICTYON Bassler

MARCUSODICTYON PRISCUM, n.var.
(illustrated in part 3, Pelecypoda)

The new variety of *M. priscum* (Bassler) differs from the typical Ordovician form as it has stolons of a larger diameter and the magnitude of the meshes which these stolons make is greater. The stolons are .1 mm. to .15 mm. wide, and make meshes 2 mm.×4 mm. wide. In the type of *M. priscum* the stolons are .02 to .03 mm. wide, and make meshes .2×.4 mm.

Besides the ordinary stolons there are also developed often a few bulbous short outgrowths in the plane of the stoloniferous meshwork. These outgrowths could be interpreted as prostrate undeveloped zooecia homologous to young stolons. In the best known of the Paleozoic stoloniferous Ctenostomata *Ascodictyon* the stolons occasionally swell into fusiform to oval structures (Condra & Elias, 1944, pl. 1, fig. 11) comparable to the short bulbous outgrowths. However, no such outgrowths have been recorded for *Marcusodictyon priscum*. As nothing is known about the biologically and taxonomically most important part, the zooecia, and in view of possible prolonged conservation of the stock which occupies a very specialized ecological niche, it seems conceivable that species *M. priscum* survived from Ordovocian to the Pennsylvanian without fundamental change in its organization.

VINELLA BILINEATA Elias, n. sp.
Pl. 40, fig. 13

The holotype and the only specimen collected represent a luxuriously developed colony upon a fragment of a large pelecypod, with more than a score of hollow centers around which radiate 8 to 10 "rays," each uniformly .12 mm. across, and averaging about 1 mm. long. Many rays or radii are distinctly double-barrelled, which is the most distinctive specific character previously unrecorded for any species of *Vinella*. "Rays" rigidly straight to gently curved. Distance from center to center from .4 to 1.2 mm.; centers only slightly wider than rays.

Discussion.—Bifid character of rays in *V. bilineata* may be understood as bunching of rays into twos, and if so, this is the second species where rays are bunched, the first being *Vinella? multiradiata* Ulrich & Bassler (1904, p. 276, pl. 68, fig. 8) from the Rochester shale (Silurian), Lockport, New York; in the latter the "radii are commonly disposed in sets of three to five." Besides having disposition of radii in sets of two, *V. bilineata* differs from *V. multiradiata* in having thinner radii and smaller number of radii around each center.

Order CYCLOSTOMATA

Family FISTULIPORIDAE Ulrich

Genus ERIDOPORA Ulrich

Eridopora ULRICH, 1882, Jour. Cincinnati Soc. Nat. Hist., vol. V, pt. 1, p. 137. ULRICH, 1890, Ill. Geol. Survey, vol. 8, p. 382,463. SIMPSON, 1897, 14th Ann. Rep. State Geol. N. Y. for 1894, p. 563. NICKELS & BASSLER, 1900, U. S. Geol. Surv. Bull. 173, p. 25,236. HERNON, 1935, Jour. Paleont., vol. 9, 672–673. BASSLER, 1935, Bryozoa, part 67 of *Fossilium Catalogus*, Animalia; p. 16,104.

Pileotrypa HALL, 1886 [part], Fifth Ann. Rep. State Geol. N. Y. for 1885, expls. p. 30. SIMPSON, 1897 [part], 14th Ann. Rep. state Geol. N. Y. for 1894, p. 562, pl. 23, fig. 8 & 12 only.

Genus *Eridopora* embraces very thin encrusting zoaria, and was originally based on two species described from the shaly limestones of the Chester series in Ohio. Ulrich does not illustrate or describe complete zoaria, which seemingly are fairly large, and he does not mention the radiating arrangement of the rows of apertures (or their lunaria) from an initial point; thus his material comprises fragments of distal parts of zoaria. His original generic diagnosis reads:

> Zoarium thin, incrusting. Cell-mouths subtriangular or ovate, and more or less oblique, with the margin strongly elevated on one side, or the "lip" may extend unequally all around the aperture, it being always more prominent on one side than on the other. Cell orifices surrounded by from one to three series of smaller, angular interstitial cells, which, when the zoarium is well preserved, are covered by an interstitial membrane. Longitudinal sections show that the interstitial cells do not form tubes, but, instead, the intertubular spaces are occupied

by vesicular tissue. . . . Type, *Eridopora macrostoma*, n. sp.

While Ulrich made no observation in regard to the initial part in *Eridopora* or of radiation of zooecial apertures, his original illustration of genotype *E. macrostoma* shows disposition of the hooded apertures in radial rows with superimposed diagonal rows in such a way that spacing of the apertures in diagonal rows is denser than their spacing along the radial rows. The disposition of the hooded apertures in some of the zoaria from the Redoak Hollow is much the same and constitutes one of the reasons for their classification with genus *Eridopora*.

Discussion.—Ulrich's original concept of genus *Eridopora* was retained essentially unchanged in the subsequent literature, even after addition to the genus of some of the Devonian species originally placed by Hall in his genus *Pileotrypa* (Hall, 1886; see Nickles & Bassler, 1900, p. 236).

Hernon describes "*E. macrostoma*(?)" and an additional species of *Eridopora*, *E. occidentalis* (1935, p. 672,673) from the Paradise formation of Arizona, both somewhat different than the original two species from the Chester but similar in the large size of encrusting zoaria (up to 3 cm. in diameter in *E. occidentalis*), in having nearly the same spacing of the zooecial apertures (14 to 15 per 5 mm.), and in the lopsided "lunaria." Hernon did not observe or illustrate any radial arrangement of the apertures that would indicate the position of the starting point of a zoarium.

Subgenus DISCOTRYPELLA Elias, n. subgen.

Description.—The material from the Redoak Hollow, which is here included in *Discotrypella*, a new subgenus of *Eridopora*, differs from all of its previously described species by the very small size of the zoaria (not over 9 mm. in diameter), their circular to subcircular outline, and the outwardly inclined to sub-prostrate position of the curved zooecial tubes. No indication of maculae (in the form of bald spots), or monticules (grouping of larger than average apertures) has been observed. In the central part of each zoarium is a circular bald spot of about 1 mm. in diameter, around which is formed the first, inner circle of hooded zooecial apertures, with the hoods opening outward from the central spot.

Type species: *Eridopora* (*Discotrypella*) *stellata*, n. sp.

Discussion.—The noted differences seem sufficient for differentiation of the *Eridopora*-like species from the Redoak Hollow at least as a subgenus *Discotrypella*. Apparently none of the previously described Paleozoic bryozoa can be placed in it, but in the material from the Pennsylvanian and lower Permian of the northern Midcontinent at the Nebraska Geological Survey a good number of small circular zoaria of *Discotrypella* have been observed. Zoaria of this kind have not been found, as yet, in the material from the Upper Mississippian at any other locality.

Encrusting circular zoaria of comparable small size are known from the lower Paleozoic (Ordovician-Devonian) under generic names *Discotrypa*, *Aspidopora*, *Petigora*, and others (all genera differentiated by Ulrich, 1883), but they all differ from *Discotrypella* by the absence of the hooded lunaria, and by the vertical to subvertical orientation of the zooecial tubes. Besides, all these genera have either monticules, or maculae, or "spiniform tubulae" (acanthopores), or various combinations of these features.

Some species of *Ceramopora* Hall, particularly the Silurian (Niagara) *C. labecula* Hall and Devonian (Lower Helderberg) *C. labeculoidea* Hall are practically indistinguishable from the Redoak Hollow form externally. If their internal structure, presently unknown, is the same as *Discotrypella*, then they will have to be removed from *Ceramopora*. Ulrich's (1890, p. 463; pl. 39, fig. 1–1b) examination of *C. imbricata* Hall, the genotype of *Ceramopora*, established that it had "no epitheca," and instead the "basal portion of zoarium composed of a cellular or spongy tissue, from which the zooecia grow out more or less obliquely." The forms referred here to *Discotrypella* have very thin wrinkled epitheca from which the zooecia grow out directly, and there is no spongy tissue comparable to that of *Ceramopora imbricata*.

Genus *Eridopora*, *s.s.*, is known only from the Devonian and Mississippian of America, while *Discotrypella* of the Redoak Hollow,

Pennsylvanian and Permian could be its dwarfed descendant.

ERIDOPORA (DISCOTRYPELLA) STELLATA
Elias, n. sp.
Pl. 42, fig. 1

This species from the basal Eskeridge shale, Big Blue Permian, Roca, Nebraska, is here introduced as the type of *Discotrypella*. This is done so that the type of the new subgenus can be based on a calcareous specimen instead of a mold as only molds are available in the Redoak Hollow material.

The only individual of *E.* (*D.*) ***stellata*** described is a small disk only 3.5 mm. in diameter, while the disks of *E.* (*D.*) ***radiata*** are two or three times as large. Zooecial tubes ascend at a sharp angle to the upper surface of the zoarium and make long radiating elevations slanting inwards from each aperture on the surface, in star-like fashion; hence the specific name ***stellata***. The radiating "hoods" are at least as long as the diameter of the apertures, and frequently are up to two times as long.

Discussion.—The long "hoods" distinguish *D. stellata* from *D. radiata* as the "hoods" in the latter are short; their elevation is noticeable for a distance of only half diameter of an aperture in the direction inward.

ERIDOPORA (DISCOTRYPELLA) RADIATA
Elias, n. sp.
Pl. 41, fig. 1a; Pl. 42, fig. 4–7

A number of well preserved molds of complete to nearly complete zoaria have been recovered. They are either nearly flat and circular, or tend to be so when their growth is lopsided. This is probably caused by abnormal encrusting growth due to unsuitable substratum. Diameter of zoaria averages 4 or 5 mm., but the radius of the largest incomplete zoarium extends about 4.5 mm. from its initial part If it were symmetrically expanded its diameter would have reached 9 mm.

The reverse or the surface of attachment of the zoaria is invariably concentrically wrinkled, as it follows the surface of the substrata only in a general way. This seems to indicate it had ability to attach itself to other bryozoa or other invertebrates when the latter organisms were alive, as the encrusting zoaria were able to adjust themselves to the slight elasticity and possible growth of the organism serving as a substratum.

Thickness of zoaria averages about .5 mm. or even less, with only slight increase toward the center, and an abrupt decrease near the outer edge. Mature zooecial tubes radiate from the center, are crowded very tightly together along the basal surface, so that only a very thin wall separates the neighboring tubes. Basal part of tubes is prostrate, the side facing the reverse nearly flat (except in the zoarial transverse wrinkling), and some tubes have a longitudinal septum, which divides their flat basal part into two subequal halves (pl. 42, fig. 6). The distal, mature part of each zooecial tube turns gradually upwards (pl. 42, fig. 7) and terminates in an obtuse angle with the upper surface. Its hooded aperture always faces diagonally away from the zoarial center. The zooecial tubes which start near this center are short and only slightly prostrate at the base; the zooecial tubes next toward the periphery become gradually longer, but the outermost tubes are underdeveloped, flat, short, and have no hooded aperture, as they consist of only immature basal parts. Similar short and flat underdeveloped zooecia are found occasionally in small concentric groups along some of the larger wrinkles of the zoarial base. The transverse outline of the basal part of the zooecial tubes is always subangular, and so is the lower part of their mature portion, wherever they continue to adhere tightly to each other. Only in the outermost part (next to the hooded aperture) does their transverse outline becomes more or less circular, and here the tubes are about as far as half of their diameter apart. The intervening space is apparently filled by mesopores which is assumed from the angular net-like or mozaic-like impression in the outer rock-matrix. There are from one to two rows of mesopores between the neighboring apertures. Usually four tightly adhered zooecial tubes can be counted per 1 mm. tangentially, but at the outer surface of the zoarium the hooded apertures are spaced more distantly, about 13 or 14 per 5 mm. in diagonal rows, and about 7½–8 per 5 mm. in radial direction.

No diaphragms, acanthopores, or maculae have been observed. All full grown zooecial tubes and their apertures are of about the same diameter. Diameter of apertures about .25 to .30 mm.

Genus CHEILOTRYPA Ulrich, 1884
CHEILOTRYPA DISTANS Elias, n. sp.
Pl. 42, fig. 8,9

Several specimens of this form recovered from locality III are placed in *Cheilotrypa*. The genus differs from all other ramose Cryptostomata by its comparatively large and distantly spaced apertures with peristomes strongly elevated posteriorly, and smooth, somewhat concave intervals between the apertures. Another important generic character is the presence of a central tube, "irregularly expanding and contracting" (Ulrich, 1884, p. 49). A mold of this tube can be seen on fig. 8, pl. 4. It shows transverse differentiation into short intervals of variable, .3 to .7 mm. diameter. The external diameter of the transversely circular zoarium is about 1.5 mm., and expands to 2.5 mm. of long diameter in elliptical section when about to bifurcate. In the proximal part of the zoarium, zooecial tubes run for a short distance along the contact with the central tube, and then curve gradually outward and cross the outer surface of the zoarium at an angle of about 45°; in the distal part of the zoarium they assume this direction at the axial tube. The internal structure of the interzooecial spaces is not preserved. The intervals between zooecial apertures average slightly less than their diameter, but larger smooth intervals occur sporadically between the apertures so that they have an appearance of small maculae (pl. 42, fig. 9). Apertures average 3 per 2 mm. along the zoarium, and usually arranged in regular diagonal rows, with nearly 4 apertures per 2 mm. along each row.

Discussion.—C. hispida of the Glen Dean, Chester has a dense spacing of the apertures, which also are arranged in diagonal rows with 3 or slightly more apertures per 1 mm. along a row. In longitudinal direction there are from 5 to 6 apertures per 2 mm. The species *Cheilotrypa regularis* described by Easton (1943, p. 139, pl. 22, fig. 3,4) from the Pitkin limestone of Arkansas has zooecia spaced 4 to 5 in 2 mm. longitudinally, the spacing intermediate, as it were, between those of the two mentioned species. Similarly, axial tube in *C. regularis* is of intermediate (even if variable) size in proportion to the external zoarial diameter. Numerical data for these three and an additional Devonian species, are taken directly from their published illustration, and entered in table 3. They illustrate the tendencies that seem to be of evolutionary significance.

Order TREPOSTOMATA
Family STENOPORIDAE Duncan
Genus PYCNOPORA Girty

Subgenus *Pycnopora* GIRTY, 1910, Ann. NewYork Acad. Sci., vol. XX, No. 3, pt. II, p. 202–204. Genus *Pycnopora* BASSLER, 1934, Bryozoa: part 67 of Fossilium Catalogus, Animalia; p. 18, 180. BASSLER, 1941, Jour. Wash. Acad. Sci., vol. 31, No. 5, p. 176, fig. 1,2. *Leioclema* ULRICH, 1890 [part], Ill. Geol. Surv., vol. 8, p. 431–432 (*Leioclema ? araneum* Ulrich only).

Type species: *Pycnopora regularis* Girty, 1910, p. 203.

Girty introduced *Pycnopora* as a subgenus of "*Lioclema*" (*Leioclema* of authors) and differing from the ordinary zoaria of this genus by very thin encrusting growth forms, "greatly reduced number of mesopores and the much smaller acanthopores" (Girty, 1910, p. 203).

Three new species of the genus were originally described by Girty but not illustrated: *P. regularis*, *P. bella*, and *P.*

TABLE 3

Species	Number of apertures per 2 mm.	Ratio of axial tube to dia.	Age
Cheilotrypa distans Elias, n. sp.	3 to 4	1:4 to 3:5	Redoak Hollow
Cheilotrypa regularis Easton	4 to 5	1:10 to 2:5	Upper Pitkin
Cheilotrypa hispida Ulrich	4 to 6	1:20 to 1:6	Glen Dean
Cheilotrypa osceolata (Hall)	about 6	1:50 to 1:10	Middle Devonian

hirsuta, all from the Fayetteville shale of Arkansas.

We are indebted to Bassler for publication of some sketches prepared from thin sections. Two sections of genotype, vertical and tangential, have been illustrated, but none of its growth forms or of the mode of arrangement of its apertures. Neither Girty nor Bassler mention any regularity in zooecial arrangement, which could have been a reason for the specific name *regularis*, but two other species of the genus: *P. hirsuta* Girty and *Pycnopora araneum* (Ulrich) have the apertures regularly arranged in "quincunx" in the first, and "radially about one or more centers" in the second of these species.

The basal epitheca of the encrusting growth form is wrinkled in the genotype, but is not wrinkled in *P. araneum*. Girty gives no generic or subgeneric significance to this character.

The genus differs from similarly thin and encrusting *Eridopora* by the absence of lunaria.

PYCNOPORA OVATIPORA Elias, n. sp.
Pl. 43 fig. 1,2

Several zoaria of this species, encrusting shells and fragments of crinoid stems have been recovered; the largest example, selected as holotype, encrusts the outer surface of a full grown valve of *Leptodesma matheri*, n. sp. The following description is based on this specimen.

The crustose zoarium is about .3 or .4 mm. thick, and is observable only from a somewhat eroded reverse, by which it adheres to *Leptodesma*. The reverse is even, and the zooecial tubes outlined upon it have an oval to somewhat diamond shape, the longest diameter measuring .25 to .3 mm. The oval bases are arranged so that their longer diameters radiate from a common center, three such centers being observable in the holotype. The oval bases are arranged in intersecting and curving diagonal rows. The whole "quincunx" pattern is such that only in a few places is it possible to count the zooecia per 1 mm. along either radial or transverse directions. It was found that in such places $3\frac{1}{2}$ oval bases occupy 1 mm. longitudinally, and 8 can be counted per 1 mm. transversely.

Because the zooecial tubes are in contact with each other throughout the zoarium, only the interstices in the angles between the tubes are filled with irregular mesopores. No acanthopores have been observed, but perhaps these are so thin that they left no inner limonitic molds in the narrow spaces between the walls of the adjacent zooecial tubes. The latter are vertical and short (.3–.4 mm.), with only a trace of proximal radial drag at their bases.

Zooecial tubes are nearly the same shape and size over zoarium, and only those at the very center tend to be subcircular. Zoarium of holotype is sub-elliptical in outline, with a radius up to 4 mm. long, or 8 mm. diameter. Neighboring zoaria coalesce imperceptibly, thus making a continuous crust. No

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EXPLANATION OF PLATE 43

FIG. *1,2*—*Pycnopora ovatipora*, n. sp., ×10. *1*, Encrusting outer surface of *Leptodesma*, n. sp. *2*, Encrusting unidentifiable shell.

3–5—*Fenestella cumingsi* Condra & Elias, reverse of proximal part of a zoarium, ×2, its detail, ×20, and the outline of zooecial chamber ×20.

6—*Cliona stellata*, n. sp., in *Spirifer*, n. sp.; and *Fenestella* cf. *F. chesterensis*, showing molds of the zooecial chambers viewed from reverse, and outer mold of the obverse.

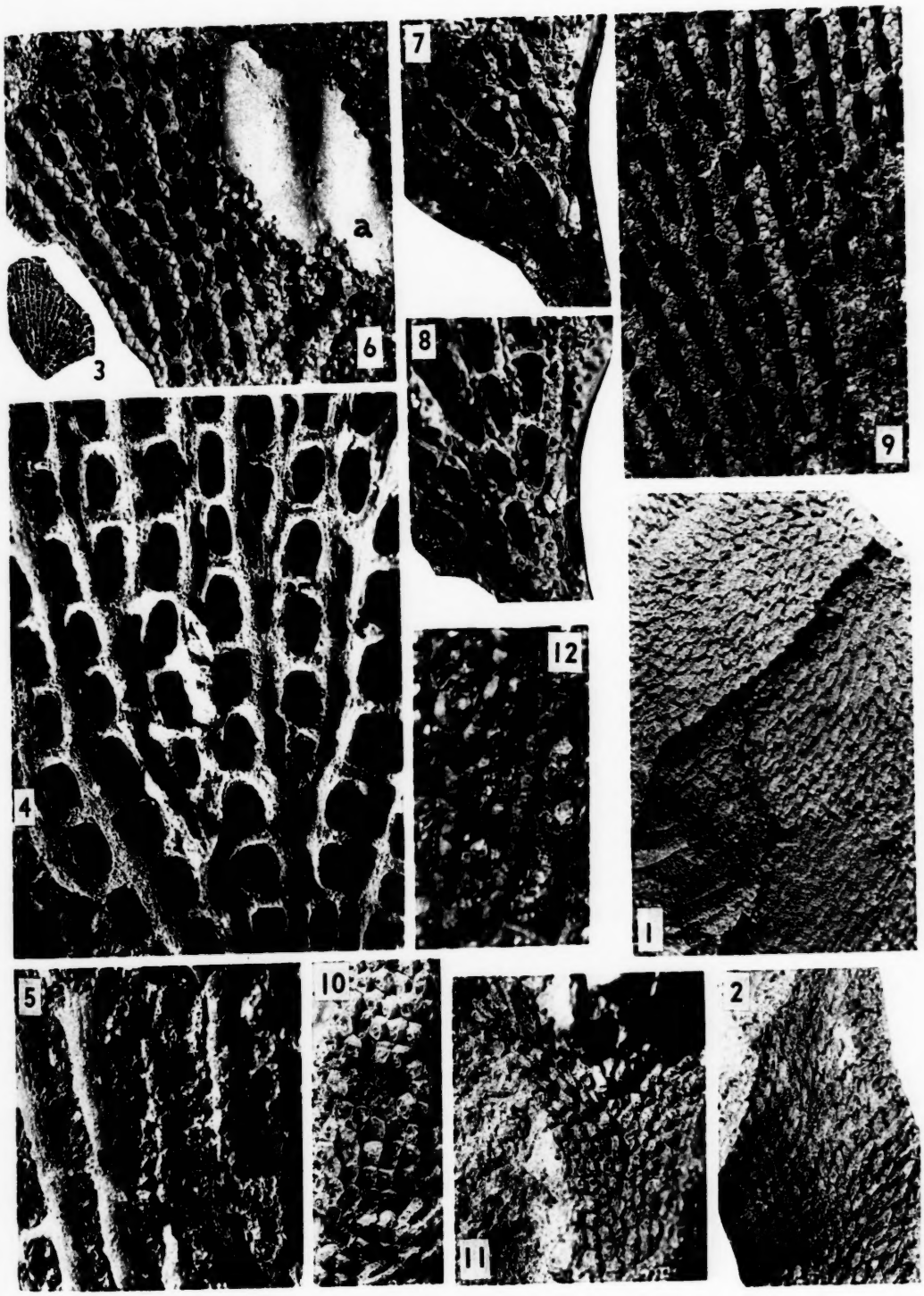
7,8—*Fenesteverta nicklesi*, n. gen., n. sp. Two views of the same spirally coiled specimen at slightly different orientation. The spirally coiled main branch has a typical polyporid arrangement of zooecia in four rows, while the lateral branches have a regular fenestellid arrangement of zooecia in two rows, ×10.

9—*Fenestella paradisensis* Condra & Elias. Inner mold viewed from reverse showing well developed lower hemisepta, ×10.

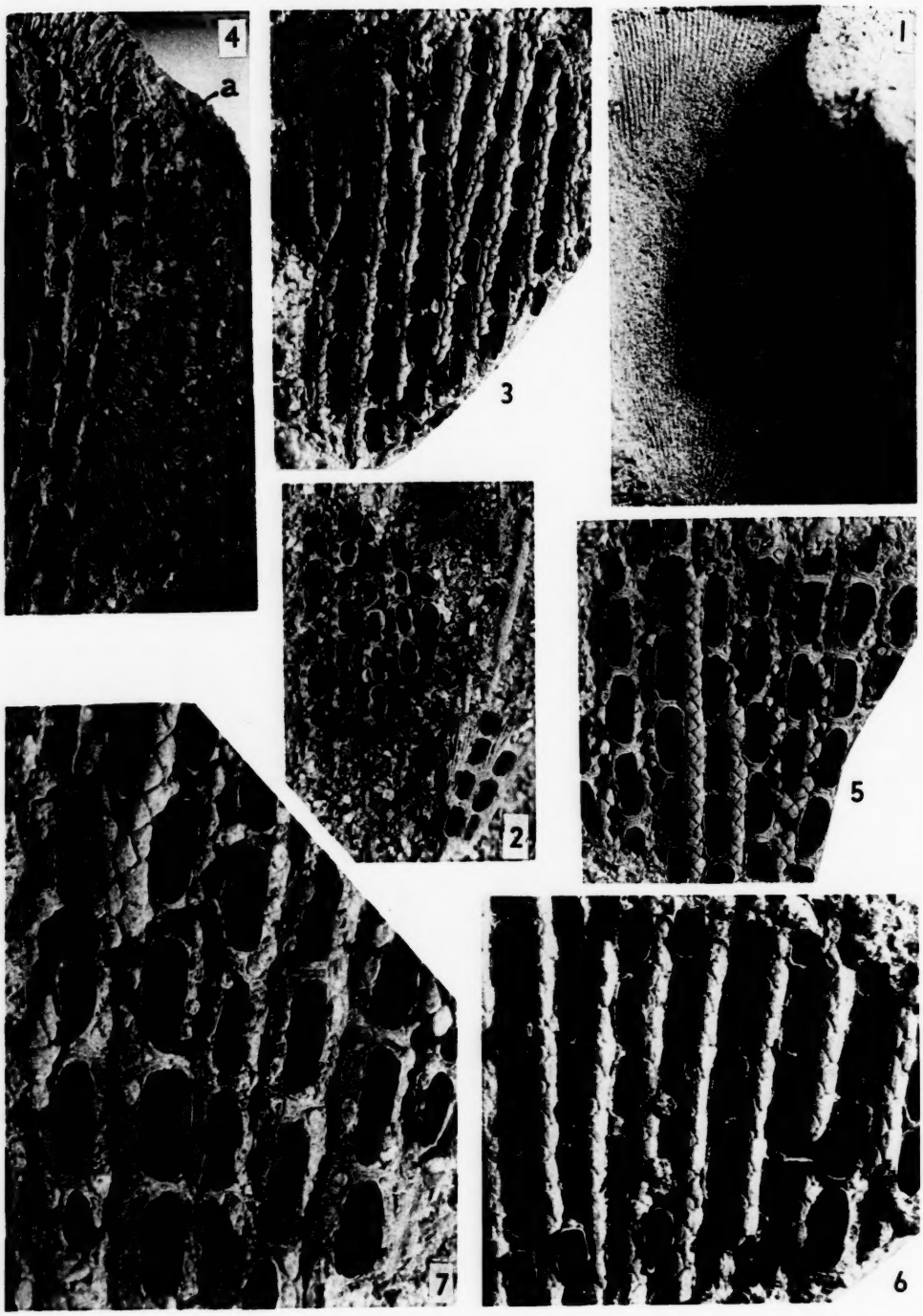
10—*Tabulipora simplex*, n. sp., Internal mold broken along a number of subparallel, centrally-perforated diaphragms of the zooecial tubes; bottom view; ×10.

11—*Tabulipora macnairi*, n. sp. Cotype ×10.

12—*Fenestella* cf. *F. frutex* M'Coy, showing molds of trapezoidal zooecial chambers, from Redoak Hollow ×20.



Maxim K. Elias



Maxim K. Elias

diaphragms can be observed, but they may be obscured by the rough preservation of the mold in the medium to fine grained sandstone.

Discussion.—*Pycnopora ovatipora* is nearest to *Pycnopora araneum* (Ulrich) from the Chester of Illinois. Both species have elliptical outlined cross-sectioned zooecial tubes, but in *P. araneum* they are not arranged in quincunx, but only "in radial rows," as Ulrich states (1890, p. 431), and each tube is traversed by densely spaced solid septa, while no septa can be observed in the zooecial tubes of *P. ovatipora*.

It seems that *P. ovatipora* has evolved from *P. araneum*.

Genus STENOCLADIA Girty

STENOCLADIA? BASSLERI Elias, n. sp.

Pl. 44, fig. 4a; Pl. 50, fig. 17,18

The largest and nearly completely preserved zoarium represents a symmetrically bifoliated growth form about .4 mm. thick, which grows on and around a flattened tube of unknown nature. The width of the thin, flattened, slowly expanding tube is from 1 to 1.2 mm.; and it is ornamented by very faint, transverse, narrow costae separated by wide intervals, about nine intervals per 1 mm. The length of tube is 11 mm., the length of the zoarium built around it is about the same. The zoarial foliation coincides with the plane of the flattening of the tube, and the opposite sides of the bifoliate zoarium are split among the flattening. The expanse of the zoarium within its plane of symmetry is unequal, 2 mm. wide on one side and 5.5 or 6 mm. on the other side. The zoarial chambers are arranged in longitudinal, somewhat radiating rows, as seen distinctly on the two reverse surfaces which originally were back to back, but cleaved along the exact plane of contact in the course of preparation. All chambers are flattened at the base along the plane of the main cleavage, but there is a shallow but sharp longitudinal groove in the middle of the flattened base of each chamber. The length of the chambers in the greater part of the zoarium is about .7 mm., measured on the reverse, and the chambers of the same row are separated from each other by a diagonal wall at variable angles of inclination. At the distal end each chamber turns sharply to a perpendicular position in relation to the zoarial front, and thus forms an oval aperture, as should be seen on the obverse. There are 5 zooecial apertures per 2 mm. in each longitudinal row. The checkerboard arrangement of the chambers and of the apertures in the neighboring rows results in diagonal rows, which curve regularly with outward convexity. The number of apertures in the diagonal rows is 9 per 2 mm. The apertures in the longitudinal rows are spaced their own diameter apart, and intervening spaces are filled with two or three rows of pores, two to four pores in a row, which are of the same nature as the interapertural pores in *Streblotrypa* and in *Strebloplax*, n. gen. here described. There are some scattered small round pores over the zoarium which are not regularly disposed, and apparently are acanthopores.

The preceding description and measurements of various details are based on the observations of the larger of the two unequal sides of the zoarium. The part of the zoarium

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EXPLANATION OF PLATE 44

FIG. *1*—*Fenestella tenax* Ulrich. External mold of the obverse of nearly complete zoarium, ×2.

2—*Fenestella cumingsi* Condra & Elias. Outer mold of the obverse (to the left), and outer mold of the reverse, ×10.

3—*Fenestella paradisensis* var. *ardmorensis*, n. var. Inner mold, from reverse, showing well developed lower hemisepta, ×10.

4—*Stenocladia? bassleri*, n. sp., on *Fenestella cumingsi* Condra & Elias. Internal mold from inside its bifoliate zoarium, split along its plane of bifoliation, ×10.

5—*Fenestella morrowensis* Mather. Internal mold of the zooecial chambers, viewed from the reverse, and external mold of the obverse, ×10.

6—*Fenestella cumingsi* Condra & Elias. Internal mold of the zooecial chambers viewed from the reverse, ×20.

7—*Fenestella ovatipora*, n. sp., showing, in part, the inner molds of the zooecial chambers, and, in part, the outer mold of the obverse with the irregularly-elliptical apertures, ×20.

on the other side of the tube is shorter and irregularly built, with zooecial tubes standing erect, up to .4 mm.–.5 mm. tall, but at two points the zoarium on this side sends out two short flat bifoliate tongues, which tend to have the same structure as the larger part of the zoarium on the other side of the tube.

A second, equally well preserved example of *S. bassleri*, demonstrates convincingly the constance of the peculiar orientation of its bifoliate zoarium in relation to substratum, so that the flattening of the substratum coincides with the medial plane of the flat zoarium. In the second example, a fairly large flat fragment of *Fenestella cumingsi* serves as a substratum and the bifoliate zoarium of *S. bassleri* grows around it (pl. 44, fig. 4a) much in the same fashion as it grows around the tube described above. In both examples the thickness of the bifoliate growth form is very near that of the substratum, so that together with the latter it forms a flat disk, with somewhat ragged edges, the core of which is formed by the substratum.

Discussion.—If the form from the Redoak Hollow belongs to genus *Stenocladia*, it provides evidence that zooecia on the opposite sides of bifoliation arise back to back, and their central grooves, by a contact, produce longitudinal canals common to the two opposite foliations (Bassler, 1941, p. 178).

The perfect symmetry of the bifoliate growth form strongly suggests its free growth within the surrounding medium (marine water), and not in a prostrate position upon sea bottom, which would have resulted in some kind of dissymmetry and by which the upper and lower sides of the zoarium could have been recognized. It is hardly possible to expect any zooecia to develop downward into the muddy or sandy bottom, as in such a position they could not receive any food. The growth of *S. bassleri* proceeded upon erect, and probably live substratum, such as an edge of *Fenestella*, a tube, or a similar object. Such growth of *S. bassleri* apparently would not interfere with the life functions of a live substratum.

The Redoak Hollow form is, in some respects, comparable to *Stenocladia frondosa* (Girty, 1910, p. 204–206; Bassler, 1941, p. 176–178, fig. 23–24). The genotype and only species of the latter was sketched by Bassler from two thin sections of the species available to him, and he states that the original specimen described by Girty is now missing. The preservation of the material from the Redoak Hollow in the form of internal molds does not permit very clear observation of the obverse, and the dissolution of the walls makes it impossible to observe the texture of the sclerenchymatous tissue and the acanthopores in it. Hence the comparison of some essential details of the obverse and of the structure of the wall is impossible. The structural characters that can be observed in the form from the Redoak Hollow permit differentiation of it specifically from *Stenocladia frondosa* and even question its possible differentiation into a new genus.

S. bassleri differs from *S. frondosa* in that its foliations are only .2 mm. wide, while the foliations in the latter are .5 mm. The zooecia in *S. bassleri* are arranged in regular longitudinal rows, and their apertures are also in regular diagonal rows, while no regularity is illustrated for *S. frondosa* by Bassler or described by Girty. This latter difference, if confirmed by further comparative observations, would indicate generic differentiation between the two species.

STREBLOPLAX CRUSTACEA
Elias, n. gen., n. sp.
Pl. 42, fig. 2,3

No attempt is made to separate generic from specific characters in the single expanse of this bryozoan, whose thin crust entirely embraces the lateral surface of a fragment of a small crinoid stem made of five joints. The encrusting zoarium differs from the previously described creeping Cryptostomata by considerable elongation of its short zooecia in the direction of growth of the crust. This elongation can be best observed in the basal part of the crust, where the zooecial chambers are closely pressed together in diagonally crossing rows of elongated diamond-like or lens-like outlines. The contacts between the successive elongated zooecia of the same row are invariably at a sharp angle averaging about 45°.

The shape of the zooecia is also peculiarly characteristic as their posterior half is very low and has a flat top while the anterior half is raised into a broad cylindrical vestib-

ulum with a sub-elliptical outline. Above the low flat roof of each zooecium several short vertical tubes with variable diameter are developed. They are not connected with the zooecial chamber, stopping short above its flat roof, and probably represent abortive zooecia at various degrees of development. As they press against the vestibula of the neighboring normal zooecia, they produce gentle vertical plications over the posterior two-thirds of their surface. This detail, coupled with the general shape of the zooecial chamber, makes its internal mold look like a crude hairbrush.

The orientation of the zoarial growth form upon the crinoid stem is quite regular: its initial part, which can be recognized by non-elongated zooecia, is located in the middle of one of the gently convex crinoid joints. As the zoarium grows, its zooecia become strongly elongated in the direction of growth, which is along the suture lines of the joints, that is, across the axis of the crinoidal stem. Only at the very edges of a joint are the marginal elongated zooecia inclined slightly toward each edge respectively. As the zooecial crust creeps over the structure between the two joints, its direction of growth turns at once by 90° and exactly parallels the axis of the crinoidal stem, as indicated by the direction of elongation of all zooecia. This direction of growth continues over all other joints throughout the preserved part of the stem.

Measurements of *S. crustacea* are as follows: crust about .15 mm. in diameter, 6 mm. in length, about 8 zooecia per 1 mm. across longitudinal rows, and about 2 to 2½ zooecia per 1 mm. along longitudinal rows.

Discussion.—The mode of preservation does not permit observation of the face of *Strebloplax*, but judging by its well preserved internal structure, it should look somewhat like *Streblotrypa hertzeri* Ulrich from the Cuyahoga shales and the Keokuk of the upper Mississippian.

Ulrich gives the following measurements for *Streblotrypa hertzeri:* diameter of stem 2 mm., oval zooecial apertures "arranged in not very regular diagonally intersecting and longitudinal series, 9 in 3 mm. diagonally and 10 in 5 mm. longitudinally" (Ulrich 1888, p. 85–86), the data are not very different from those in *Strebloplax crustacea.*

Genus TABULIPORA Young

Tabulipora YOUNG, 1883, Ann. Mag. Nat. Hist., ser. 5, vol. XII, p. 154.

Stenopora FOERSTE, 1887, Bull. Denison Univ. Sci. Lab., vol. 2, p. 85. ULRICH, 1890, Ill. Geol. Survey, vol. 8, p. 375,436. NICKLES & BASSLER, 1900 [part], U. S. Geol. Survey Bull. 173, p. 33,409 [Only "American species" with diaphragms "perforated centrally."] CONDRA, 1903, Nebr. Geol. Survey vol. 2, p. 40. GIRTY, 1910, N. Y. Acad. Sci. Ann. vol. 20, No. 3, p. 196. LEE, 1912, Mem. Geol. Survey Great Brit., Pal., vol. 1, pt. 3, 140–150. ULRICH, 1913 [part], in ZITTEL, EASTMAN Paleontology, 2d Am. ed., p. 335.

Tabulipora GIRTY 1915, U. S. Geol. Survey Bull., 593, p. 30–31. GIRTY 1915, in HINDS & GREEN, Mo. Bureau of Geol. and Mines, 2nd ser., vol. 13, p. 339. SAYRE 1930, Kans. State Geol. Survey, Bull. 17, p. 88.

In 1912 Lee restricted the use of generic name *Tabulipora* to the species with irregularly thickened walls in the mature or cortical zone of the zoaria, and having solid or imperforated tabulae or diaphragms. Taking Lee's analysis into account, Girty (1915, p. 30) pointed out that "apparently there are no forms in the American Carboniferous which should be referred to *Stenopora* as now understood," in restricted sense, as suggested by Lee, "unless it should prove that *Batostomella* was the same genus." The analysis of some species from the Pennsylvanian of Missouri which he placed in *Batostomella* (Girty, 1915a, p. 323–339) did not settle the latter problem, and led to a further difficulty regarding the differentiation of *Batostomella* from *Rhombopora.* As Girty points out "Lee has found . . . that the perforation in an entire group of English species of *Tabulipora* is not central but marginal and diaphragms constructed in this way are hardly distinguishable from hemisepta" (Girty, 1915a, p. 324). Nevertheless American species formerly classified with Lonsdale's genus *Stenopora*, and whose diaphragms are centrally perforated, are now re-classified with *Tabulipora*, and this practice is here followed.

Two encrusting and one ramose species of this genus are recognized in the material from the Redoak Hollow.

TABULIPORA SIMPLEX Elias, n. sp.
Pl. 43, fig. 10

The single 3 mm. × 6 mm. fragment of this form is a part of a small crustose zo-

arium only .6 mm. thick with a very thin and flat epitheca. All zooecia are of nearly the same size; about 4, seldom as many as 4½, in 1 mm. of space. The walls between them are very thin, and, due to tight adherence to each other, the chambers have a polygonal cross section throughout. Their immature parts are about 1 mm. long, polygonal in cross section. These immature parts lay prostrate, parallel to each other along the flat base of the zoarium. Each is about .1–.15 mm. wide, but the width rapidly increases to twice as much when the zooecia turn abruptly at an obtuse angle of 130°–140° and become mature. Two or three diaphragms cross the intermediate and mature parts of a zooecium; they are plane and all are centrally to subcentrally perforated, the outline of perforation varying from round to elliptical, and the diameter from ⅓ to ½ of their width. The distance between the diaphragms is the same as, or larger than their diameter.

There is certainly no room for mesopores or thickening of walls anywhere in the zoarium, nor are there any acanthopores. In a few places there are narrow columnar spaces where three or more zooecia make interstices, where ordinarily acanthopores are readily developed in most species of *Tabulipora;* and when they are present in the corners or along the walls between zooecia they usually protrude into zooecia: the thinner the wall, the sharper the protrusion, but no acanthopores can be observed in the example from the Redoak Hollow, nor can any linear impressions be detected in the very thin walls from the would-be acanthopores.

Discussion.—All previously known American species of *Tabulipora* have greater or lesser number of acanthopores, and *T. simplex* differs from them in this respect. Nearest to it is *T. emaciata* (Ulrich, 1890, p. 438, pl. 74, fig. 2,2a) from the Keokuk of Illinois. The latter species has polygonal apertures, no mesopores, and its centrally perforated diaphragms are as wide as their own diameter apart or nearly so, as in *T. simplex.* Also its epitheca is as thin as in the latter species, but it is wrinkled; it differs also in having a few acanthopores protruding into the walls of the zooecia, and its zoarium develops monticules made of larger zooecia. *Tabulipora cestriensis* has less similarity to *T. simplex* as it has a thick and wrinkled epitheca and more numerous acanthopores.

TABULIPORA cf. T. TUBERCULATA Prout
Pl. 40, fig. 14; Pl. 50, fig. 19

Some small encrusting zoaria, up to 1 mm. thick, can be generally referred to *Tabulipora* because their zooecial tubes are subperpendicular to the surface of attachment, and, in the narrow intervals between them, are developed distinct acanthopores. Zooecial tubes are spaced closely; the spaces between are from ¼ to ⅓ of their diameter. 4½ to 5 zooecial tubes can be counted per 1 mm. Their apertures are apparently circular and have no lunaria. Numerous acanthopores are distributed somewhat irregularly in a single row between the zooecial tubes.

TABULIPORA MACNAIRI Elias, n. sp.
Pl. 42, fig. 11; Pl. 43, fig. 11

Branches from 1.4 to 2 mm. in diameter, frequently bifurcating at 60° to 90° angles. Zooecial tubes straight in the central part, which occupies about ¼ to ⅓ of the diameter, and curves to periphery in the transitional region, at first gradually, then becoming nearly straight and inclined at an angle of 30° to 45° axis, and then turning again sharply to subperpendicular direction when entering cortical region .15 mm. thick. About 4 zooecia per 1 mm. of length of the periphery, and 5 per 1 mm. in diagonal rows, but the tubes gradually reduce their diameter toward the central core, where they average only ⅓ to ½ of their largest diameter. Tubes are irregularly angular in cross section, and the inside surface of walls is gently and irregularly transversely wrinkled. Each tube is traversed by one to three, but mostly two diaphragms, usually spaced about as wide as their own diameter apart and located at and slightly under the cortical region. Diaphragms are widely perforated.

Some isolated and slender tubes are occasionally observed in the cortical region, seemingly undeveloped zooecial tubes, not true acanthopores. Diameter of these odd and very much scattered tubes is quite variable, from about .03 or .04 mm. to about .15 mm.

Walls between zooecial tubes are very

thin, but expand suddenly up to .1 mm. thick in the cortical region. Questionable acanthopores are observed occasionally within the wall thus thickened.

Apertures arranged in sub-regular diagonal pattern, but observation of their arrangement and shape is very difficult because of the peculiar mode of preservation of the species in the form of internal molds.

Discussion.—Although many ramose species of *Tabulipora* (*Stenopora*) are known from the Carboniferous of America, most of them described by Ulrich, the single ramose species from the Redoak Hollow is different from them in that they all possess acanthopores, while *T. macnairi* has very few or none.

Only *Tabulipora gracilis* from the Fayetteville shale (upper Mississippian) of Arkansas, described but not illustrated by Girty (1910, p. 198–199), seems comparable to *T. macnairi* in ramose growth form and a few other features. Girty states that in his species "mesopores appear to be few," and "acanthopores nearly absent," though both these structures are better developed "in a second specimen than in that from which this description is drawn" (Girty 1910, p. 199). While the comparison with this species is handicapped by the absence of illustrations, it is possible to point out from its description alone at least three characters which distinguish it from *T. macnairi;* it has "tabulae few and irregularly distributed," while in the present species the diaphragms (tabulae) are located invariably at the very periphery of a branch; Girty's species is said to have only 5 or 6 zooecia in 2 mm., while in the new species there are 7 to 8 zooecia per 2 mm. along the surface of the branches.

Genera RHABDOMESON Young & Young, and RHOMBOPORA Meek

Critical review of these two genera is essential for understanding of the following description and taxonomic treatment of the ramose forms from the Redoak Hollow. The two genera are similar externally, but differ internally: in *Rhabdomeson* zooecia arise from axial tube, while in *Rhombopora* there is no axial tube and zooecia arise from geometrical axis.

Rhombopora is one of the most common among Paleozoic genera, and in a broad sense ranges from Silurian to Permian. However, this comprehensive genus lends itself to an effective differentiation into other genera on the evidence of external pattern of zooecial apertures and ornamentation, as McNair & Bassler show by recent segregation from it of *Hyalotoechis* (1942), *Saffordotaxis* (1952), *Goldfussitrypa* (1952), and *Nicklesopora* (1952). The segregation of these and the mentioned four genera by McNair and Bassler necessitates re-definition of *Rhombopora* as follows:

Zoarium cylindrical, branching, with zooecia arising from geometrical axis; internally differentiated into axial or "immature" region, where zooecial walls are uniformly thin; and cortical or "mature" region where these walls are thick; externally differentiated into regularly symmetrical diagonal rows of apertures, and less regularly expressed longitudinal rows; megacanthopores and acanthopores at intersections of diagonal ridges separating apertures; ridges smooth or tuberculate; mesopores absent; diaphragms and hemisepta may be present.

This diagnosis is also applicable to *Rhabdomeson* except the latter possesses an axial tube in place of a geometrical axis.

Rhabdomeson (*Rhombopora*), as a phyletic sub-genus

Taxonomic treatment for the ramose bryozoans from the Redoak Hollow is unusually difficult for the following reasons:

(1) These bryozoans are morphologically transitional between the genera *Rhabdomeson* and *Rhombopora*, that is the rhabdomesontid axial tube is present in some parts, but never in all parts of a zoarium.

(2) Their transitional character is displayed in the collected basal and proximal parts of zoaria, while no basal parts of *Rhabdomeson* is known.

In view of this a question may arise whether the basal and proximal parts here described could be, at least tentatively, referred to either *Rhabdomeson* or *Rhombopora*. However, in the numerous examples of *Rhabdomeson* from all over the world the axial tube is present throughout examined parts of zoaria, and no axial tube was ever

* The author would prefer to indicate "phyletic subgenera" by a special symbol, *i.e.* square brackets.—EDITOR.

discovered in any part of any forms of *Rhombopora*. There is a good reason to regard the three species of the described group of morphologically transitional forms as phyletically transitional, and to classify them into a transitional *Rhabdomeson* (*Rhombopora*) genus (Elias, 1949, p. 149). This classification is in harmony with an apparent development of the genus *Rhombopora* in restricted sense at about the age to which the Redoak Hollow fauna belongs, and rhabdomesontid type of a branch in ontogenetically early stage of zoarium means recapitulation of its ancestral character.

A genus could be instituted for the transitional zoaria, the three kinds of which are classified here as *Rhabdomeson* (*Rhombopora*). However, such taxonomic move would be unpractical. Most fragments encountered belong to distal parts of zoaria where there is no axial tube, and thus they are indistinguishable from genus *Rhombopora;* and conversely, a few fragments from the proximal part of zoaria, in which axial tube extends throughout, cannot be distinguished from *Rhabdomeson.*

Because the specimens are molds, and the axial tubes in them are indistinguishable in shape and size from fragments of straight spines of branchiopods which are frequently found with the bryozoans in the Redoak Hollow, the possibility had to be seriously considered that the apparent axial tubes were fragmentary brachiopod spines. Such spines are known to serve as bases for some bryozoan encrustations. If specimens with unleached calcium carbonate could be collected, there would have been no difficulty deciding whether it is an axial tube or merely a brachiopod spine. After a long and determined search through the collected material from the Redoak Hollow, one specimen (pl. 47, fig. 15) was eventually found, that has its axial (very thin) tube partly calcareous, its substance is opaque, and certainly not that of a brachiopod spine. Besides, this tube is not smoothly cylindrical, as all brachiopod spines are, but has somewhat ragged outline, such as occurs occasionally in the axial tube of *Rhabdomesons* (Bassler, 1929; pl. 13, fig. 2; 1953, text-fig. 91-1c). Furthermore, the axial tubes in all other specimens have their calcium carbonate replaced by earthy to spongy ferruginous substance without a trace of concentric foliation which is so typical of brachiopod spines.

The material from the Redoak Hollow includes apparent basal parts previously unrecorded for any species of *Rhabdomeson*, hence no comparison with the latter's basal part is possible. There is good reason to expect, however, that the basal part of *Rhabdomeson* would contain an axial tube just as observed in proximal as well as distal parts in all its known fragmentary distal specimens. All the specimens referable to the transitional subgenus *Rhabdomeson*—(*Rhombopora*) possess axial tubes in their proximal part, and in some there is a basal tube-bearing a branch in which the zooecia diverge in two opposite directions from a narrow central zone where the zooecia are subperpendicular to the axis. Somewhere in the central zone there must be zoarial ancestrula or its equivalent, and the axial tube apparently antedates it in the colonial ontogeny.

Young & Young (1874, p. 337) describe in *Rhabdomeson gracile* "a hollow axis formed by a thin calcareous tube," and claim that "both axis and cells are filled sometimes with amorphous calcareous matter or with clay sediments." Bassler (1929, p. 69) states that "the central axial tube is not an integral part of the zoarium because it is filled with material from the surrounding sediments," and believed that "as is the case with many modern bryozoa, the zoarium was probably attached to the slender radicels of algae or similar organism of perishable nature which disappeared entirely after death leaving a hollow space to be filled with mud or other material."

However, in the species of *Rhabdomeson* from the Pennsylvanian of Texas, Moore (1929, p. 141–148) described and illustrated numerous diaphragms traversing the axial tube, and I have also found diaphragms traversing the axial tube in some specimens of Scottish *Rhabdomeson gracile.* Hence axial tube in this genus could not possibly be originally hollow, but was filled with some kind of soft or liquid organic substance, and its occasional filling with surrounding matrix must have been a secondary phenomenon.

TABLE 4

Species	Axial Tube	Zooecia	Hemisepta	Diaphragmus	Megacanthopores	Tori	Notes
Rhabdomeson (Rhombopora) foerstei, n. sp.	Changing distally to geometrical axis	Short and uniformly wide	None	None	Not preserved	Coincide	All parts of zoarium collected
Rhabdomeson (Rhombopora) rogersi, n. sp.	In primary, branch only	Long and slender, narrowing near axis	Superior and inferior	None	Preserved as molds	None	Only specimen collected is proximal part of zoarium
Rhabdomeson (Rhombopora) ulrichi, n. sp.	In primary branch only	Long and uniformly slender	None	1 or 2 in zooecium, widely perforated	Preserved as molds	Directly under meganthopores	All parts of zoarium collected

New morphologic term *torus* (plural tori) is introduced for description of ornamental swellings that are not elevated parts of acanthopores or megacanthopores, though are comparable in size with the latter. Prominent rounded elevations occur regularly just under megacanthopores in *Rhabdomeson* (*Rhombopora*) *ulrichi*, n. sp. and hence appear to have some relation to them, but their biologic meaning is obscure.

For holotypes of each of the three new species the proximal parts of the zoaria are selected, where rhabdomesontid or axial tube-bearing branches are combined with rhomboporid or tube-less branches.

For purpose of better comparison the principal data on the three described species are entered in Table 4.

RHABDOMESON (RHOMBOPORA) ROGERSI
Elias, n. sp.
Pl. 50, fig. 12–16

The single specimen and holotype is a basal part of zoarium, consisting of a primary straight branch .7 mm. thick and 4 mm. long, that has an axial tube, and a tubeless secondary straight branch .6 mm. thick and 3 mm. long arising at 90° at the short bulbose end of the primary branch. At this end the zooecia radiate from the blunt end of .4 mm. thick axial tube. In the long side of the primary branch the immature parts of the zooecia are short and sub-rectangular in cross-section and adpressed to the axial tube; they make 90° turn to enter the cortical region, which is about .15 mm. thick. Distinct superior hemiseptum is well developed at this turn. Single megacanthapore usually occurs at the angles of intersections of diagonal rows of intermediate spaces, but at some places a crowd of many megacathopores takes the place of an aperture.

In the secondary branch the zooecia at first are thick and rise at about 30° angle from the geometrical axis; and grow wider, as they curve very gently outward. They are angular in cross-section, have a thin inferior hemiseptum directed at about 45° outward, and a more prominent superior hemiseptum where they enter the cortical region. Axial or immature region occupies about $\frac{3}{4}$ of outer diameter of the branch. Apertures elliptical with longer diameter along axis, about half the size of their own diameter apart, sub-regularly arranged in diagonal and longitudinal rows, with 4 apertures per 1 mm. both longitudinally and diagonally. 1 to 2 megacanthopores at each angle of intersections of the rows, tending to line longitudinally.

RHABDOMESON (RHOMBOPORA) FOERSTEI
Elias, n. sp.
Pl. 47, fig. 15; Pl. 49, fig. 18; Pl. 50, fig. 1–7

Two proximal parts and many distal parts of zoaria recovered. The specimen illustrated on Pl. 49, fig. 17, is selected for holotype. In this a slightly curving primary branch has an axial tube in proximal part, but none in distal part, while its outer diameter remains .6 mm. unchanged. A secondary branch, that has no axial tube, diverges at about 60° from the proximal part of the primary branch. Zooecia are invariably short, transversely angular, and uniformly wide, except at the very inception, where their bases are angularly conical.

The second proximal specimen of a zoarium has a 2 mm. long primary branch with .2 mm. wide axial tube, from which zooecia diverge toward its both ends. Secondary tube-less branch, .7 mm. wide, rises perpendicular to primary branch at its swollen center, and at a distance of 3 mm. from it, bifurcates at about 60°. At this point a bulbous, 1.2 mm. wide body diverges also, apparently an ovicell. At variable distance of 1 to 2 mm. from this body the zooecia are three to five times thinner than normal (and the spaces between them correspondingly wider) so that they could be hardly occupied by polypides. This phenomenon could be the result of the development of the large ovicell. The surface between the apertures is shagreened and ornamented by sporadically developed nodes.

Distal parts and discussion. Distal parts are not substantially different from proximal parts, except by the absence of axial tube. Megacanthopores may be assumed to exist, as there are prominent nodes or tori arranged in the same position at the intersections of the diagonal interspaces, as the tori and megacanthopores in *R.* (*R.*). *ulrichi;* but no molds of tubular megacanthopores are observed, contrary to the common occurrence of such in all specimens of *R.* (*R.*) *ulrichi.*

Distal parts of the species are slightly less common than *R.* (*R.*) *ulrichi.* The two species are similar externally in size, usually have diagonally arranged rows of longitudinally elongated oval apertures, and longitudinally paired would-be megacanthopores. However, *R.* (*R.*) *foerstei* has shorter and wider zooecia with less abrupt change in diameter and in orientation of the immature and mature parts. The inner or immature part of the zooecia is straight and inclined only about 45° to the axis, and the diameter expands outward very gradually. The outer or mature part of the zooecia makes sharp angle with the immature part and is strictly perpendicular to the surface. Zooecia are slightly constricted in the middle of their outer (mature) part.

RHABDOMESON (RHOMBOPORA) ULRICHI Elias, n. sp.

Pl. 42, fig. 10; Pl. 49, fig. 16, 17; Pl. 50, fig. 8–11.

The only recovered proximal part illustrated in Pl. 47, fig. 13, 14 is designated holotype. It consists of a primary branch 5 mm. long and about .8 mm. wide more than half of which contains .2 mm. wide axial tube. Tube-less secondary branch, with only its base preserved, rises from a swollen middle part of the primary branch. Zooecia inclined about 45° to the axial tube, diverging from about the middle of the primary branch toward both its ends. General character and arrangment of zooecia is the same throughout zoaria and is described below.

Slender, occasionally (at longer than 10 mm. intervals) bifurcating branches .8 to 1 mm. in diameter, covered with longitudinally elongated oval apertures the width of their own diameter apart and usually arranged in intersecting diagonal rows. The surface between the apertures is ornamented by two kinds of nodes: the larger nodes or tori with the tubes of megacanthopores at their upper edge, spaced nearly regular, occasionally combining in pairs which fall in line with the apertures above and below them; but about as frequently only one

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EXPLANATION OF PLATE 45

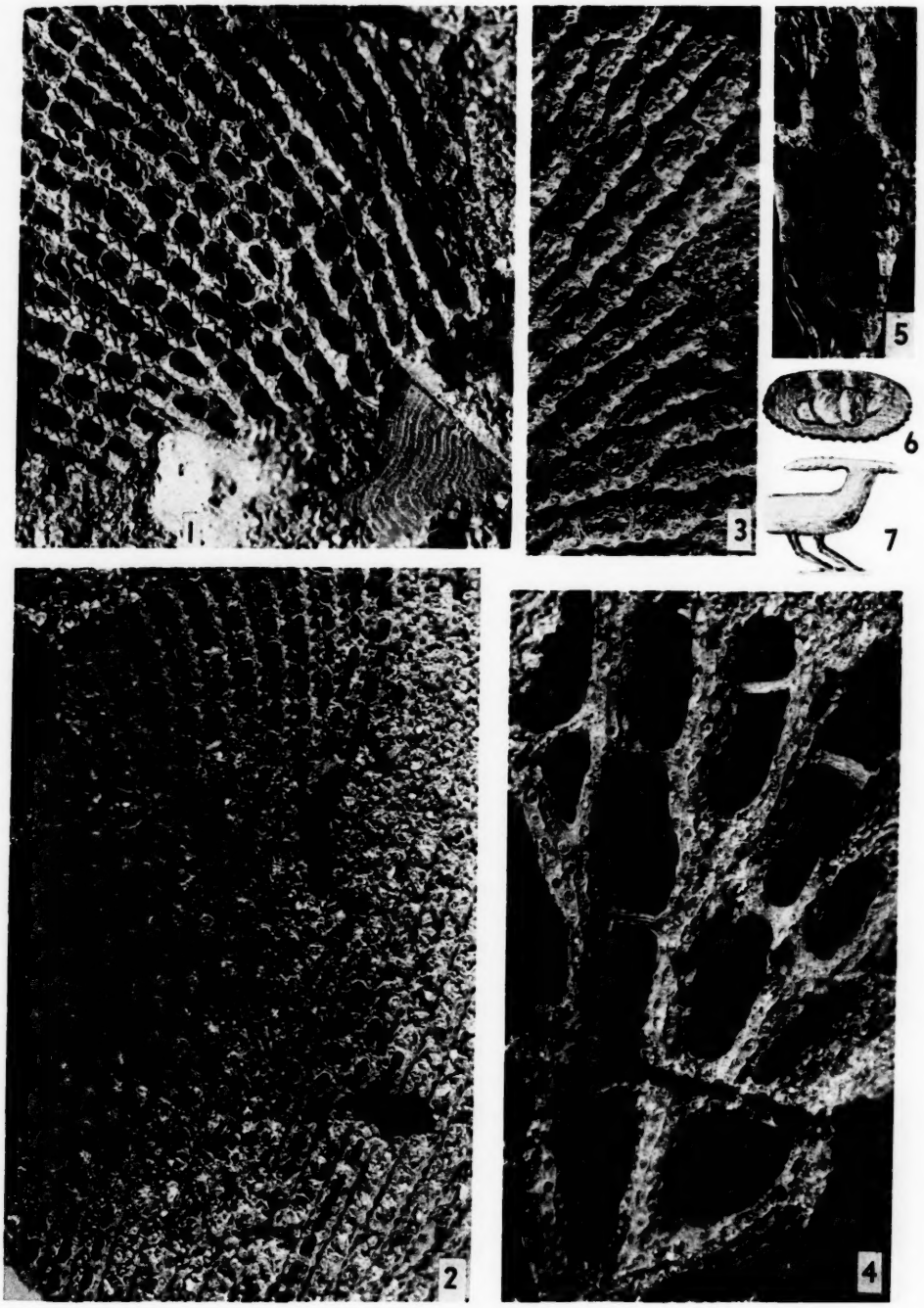
FIG. *1*—*Fenestella cumingsi* Condra & Elias, in part internal mold of zooecial chambers viewed from reverse, and in part external mold of obverse; and *Turrilepas*, n. sp. (in lower right corner, marked *a*), ×10.

2—*Fenestella serratula* Ulrich. External mold of the obverse of central and lateral part of a mature zoarium with conspicuously developed carinal nodes, ×10.

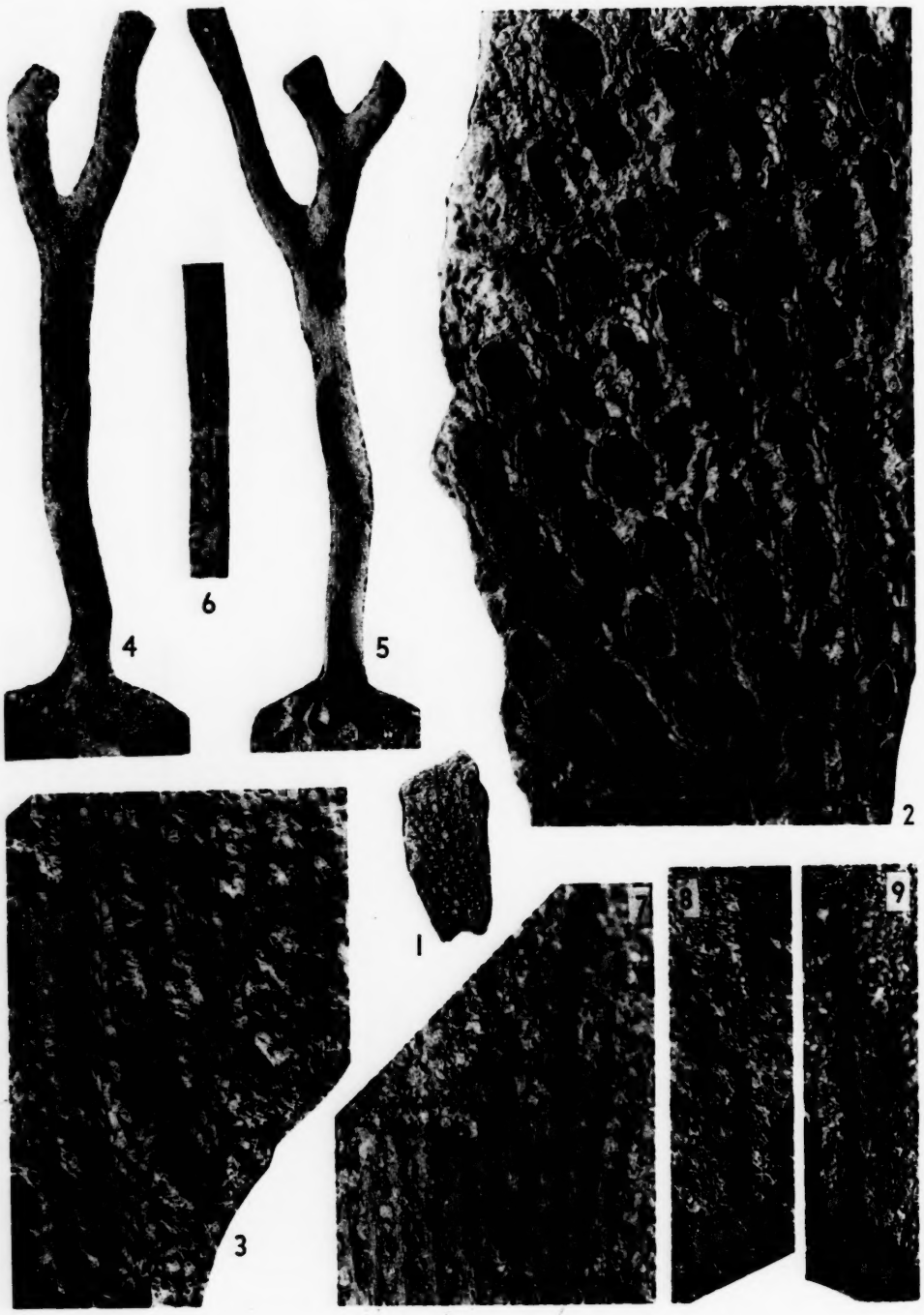
3—*Fenestella* cf. *F. chesterensis* Condra & Elias. External mold of the obverse, ×10.

4,5—*Polypora debilis*, n. sp. *4*, Holotype, external mold of the obverse, with a few internal molds of the zooecial chambers attached (in the right upper corner), ×10. *5*, Smaller fragment, external mold of the obverse, ×10.

6,7—Cross-section of branch, ×20; and lateral view of internal mold of zooecial chamber, with two geniculate pores on reverse (dorsal) side, ×30.



Maxim K. Elias



Maxim K. Elias

node (and acanthopore) occurs between the neighboring aperatures; the smaller nodes are more numerous and are scattered without noticeable regularity. From 3 to 5 apertures may be counted longitudinally, while their number in the regular diagonal rows is more stable, 5 to 5½ per 1 mm. About 20 rows of apertures can be counted around 1 mm. diameter branches. Internally the immature portion of zooecial tubes in the axial region is clearly differentiated from that in mature or cortical zone by a sharp change of diameter and of direction of the zooecial tubes, from sub-longitudinal in the axial region to transverse in the cortical zone. A few widely spaced and centrally perforated transverse diaphragms traverse the slender immature parts of the zooecial tubes. The cortical zone is about .1 mm. thick, and the long diameter of the tubes in it and at their apertures is also .1 mm.

Most characteristic for the species are longitudinally paired nodes (acanthopores) and sharp differentiation of the cortical zone.

Genus STREBLOTRYPA (ex Ulrich) Vine

An occurrence of a bryozoan externally indistinguishable from *Streblotrypa nicklesi* but internally like *Rhabdomeson* poses a problem. Its occurrence with abundant *Streblotrypa nicklesi* is highly suggestive of close relationship. The axial tube containing the form could be considered to branch out phyletically from the ordinary tube-less *S. nicklesi*, axial tube considered an innovation. However, the example of *Rhabdomeson* here discussed is indicative of axial tube to be comparatively primitive, and its occurrence in some specimens with an exterior of *Streblotrypa nicklesi* may be interpreted as recurrence of an ancestral feature. In order to verify this hypothesis an attempt was made to find the axial tube in some specimens of the earliest *S. nicklesi*, such as occurring in the Menard of Sloans Valley, Kentucky. Indeed, in one out of six thin sections prepared a fairly thick and straight axial tube was found.

If the occasional presence of an axial tube in *S. nicklesi* be considered an ancestral feature, its evolution from *Rhabdomeson* may be contemplated. However, perhaps it could have diverged from the Devonian *Cheilotrypa ostiolata* (Hall) originally placed in *Trematopora*. Ulrich's thin sections of this species (1884 pl. 3. fig. 7,7a) show thin and only slightly variable in diameter "axial tube," and according to Hall the apertures in the species have raised peristome, but no lunaria. As discussed under *Cheilotrypa* its evolution was toward a larger and more variable axial tube, while *Streblotrypa* could represent a parallel evolutionary trend from *C. ostiolata*, with axial tube gradually reduced and eliminated.

STREBLOTRYPA NICKLESI Ulrich
Pl. 49, fig. 11–15

Streblotrypa nicklesi, ULRICH 1884, (Manuscript) VINE, 1884, Proc. Yorkshire Geol. Polyt. Soc., vol. 8, p. 107, pl. 21, fig. 4,5 (Lower Carb. of England). ULRICH, 1890, Ill. Geol. Surv.; vol. 8, p. 403,667–668; pl. 66, fig. 9–9c. NICKLES & BASSLER, 1900, U. S. Geol. Surv. Bull. no. 173. p. 421. HERNON, 1935, Jour. Paleont., vol. 9, p. 677–678.

This ramose species is well represented in the Redoak Hollow, and is easily recognized by the development of numerous pits below each aperature.

In the examples from the Redoak Hollow the diameter of straight to somewhat undulating branches is up to .6 mm.; they multiply by bifurcation at about 50°.

EXPLANATION OF PLATE 46

FIG. *1–3*—*Polypora* (*Polyporella*) *ovicellata*, n. sp. Larger part of the holotype, showing in part internal molds of the zooecial chambers viewed from the reverse, and in part the outer mold of the obverse. *1*, ×2; *2* & *3*, ×10.

4–6—*Thamniscus erectus*, n. sp., ×10. *4,5*, Holotype, growing upon the reverse of *Polypora debilis*? External mold of the obverse and external mold of the reverse. *6*, Internal molds of the zooecial chambers in a side view, and external mold of the side.

7–9—Spiniferous "appendages" upon *Fenestella serratula* Ulrich. *7*, Three "appendages" developed in parallel position from the ends of three adjacent branches. A single "appendage" developed from the end of a branch, obverse and reverse, ×10.

Spacing of the oval to subcircular apertures is about 4½ to 5 per 2 mm. in each row longitudinally. There are about 14 rows around a .6 mm. diameter branch. According to the description by Ulrich (1890) the bifurcating branches of the species are about .5 mm. in diameter, with 12 rows of apertures around a branch, and with 6 apertures per 2 mm. in each row. Only one character mentioned by Ulrich for *S. nicklesi*, the development of lower hemisepta at a distance of .2 to .3 mm. from the apertures, has not been observed in the examples from the Redoak Hollow, but this character may not be constant in the species. In these examples the spacing of zooecial apertures is somewhat wider than as measured by Ulrich, and is the same as measured by Hernon in *S. nicklesi* var. *occidentalis* (Hernon, 1935, p. 678). The latter differs from the Redoak Hollow examples in being much more robust, to 1.5 mm. in diameter, and having up to 20 rows of apertures around the branches.

Discussion.—Streblotrypa prisca (Gabb & Horn) and *S. merceri* Morningstar from the middle part of Pottsville of Ohio are similar species, but they differ from *S. nicklesi* in a much smaller number of pits, which are usually arranged in only two longitudinal rows below each aperture, with two to three pits in each row. The species from the Redoak Hollow invariably has three rows of pits, with 5 to 6 pits in each row. Clearly, *S. nicklesi* survived from Chester into the Redoak Hollow with little, if any change. Neither Mather nor Girty record any species of *Streblotrypa* from the Morrow, but the collections of the Nebraska Geological Survey contain *S. nicklesi*, *S. prisca* and *S. merceri* in the upper Morrow at Ardmore and Chockie, Oklahoma, and *S.* cf. *S. nicklesi* in the Brentwood of Arkansas.

Order FENESTRATA, Elias & Condra, n. order
Genus FENESTELLA Lonsdale

Because *Fenestella* is treated in some detail elsewhere (Condra & Elias, 1944; Elias, 1956; Elias & Condra, in press) it is sufficient to mention here that the genus is distinguished from *Fenestrellina* D'Orbigny by the regularity of its meshwork. That is the branches and dissepiments are at uniform intervals in *Fenestella* but not so in *Fenestrellina*, which is restricted to the Mississippian.

The regularity of the meshwork in *Fenestella* (and also in *Polypora* and a few other fenestrate genera) permits an expression in form of mesh-work formula highly characteristic for a species. The formula was devised by Nikiforova & Nekhoroshev and was used by Condra & Elias (1944, etc.). It consists of four digits: first indicates number of branches per 10 mm.; second, number of dissepiments (or fenestrules) per 10 mm.; third, number of zooecia (or their apertures) per 5 mm.; and fourth numbers of carinal nodes per .5 mm.

Because of the very large number of species in *Fenestella* it is convenient to segregate them in groups, characterized mostly by the (1) degree of coarseness of meshwork (as expressed by meshwork formula), (2) degree of stabilization of zooecial apertures in relation to dissepiments, (3) outline of zooecial chamber, besides other characters.

Nine out of eleven species from the Redoak Hollow are referable to five groups among thirteen established by Elias & Condra (in press), and the remaining two species are segregated into a new group typified by *Fenestella cestriensis*.

(Group of *Fenestella basloensis*)

FENESTELLA EXIGUA var. SPRINGERENSIS Elias, n. var.

Pl. 42, fig. 13–15

Several well preserved molds of this *Fenestella* were recovered from localities No. 1 and No. 3. They have all the characters of a typical Upper Mississippian species, *F. exigua* Ulrich, but differ in having fewer fenestrules per same distance, and in having larger number of carinal nodes. The Redoak Hollow form has elongated sub-rectangular fenestrules, with 3½ to 5 zooecia per fenestrule. Branches are straight and slightly wider than fenestrules, with a fairly prominent carina adorned by slightly elongated nodes, which are arranged in one row. Dissepiments are about ½ to ⅔ as wide as branches, slightly depressed on obverse and reverse, distinctly longitudinally grooved on obverse. Branches and dissepiment smooth on reverse, with scattered very small pimples which are tending to be arranged in longitudinal rows. Apertures round to

slightly oval, with sharply outlined and elevated peristomes. The surface between peristomes, as wide as apertures, sharply longitudinally grooved. Opercula occasionally preserved, located slightly below (inside) peristome, distinctly upwardly convex and with small circular depression, usually at or near its center. Zooecial chambers pentagonal in outline, seldom tending to become triangular below the points of bifurcations, where also one or two zooecia are added to form the third row.

Very faint longitudinal grooves on the surface of bases of zooecial molds.

Meshwork formula: 19–20/12–13//23–24/18 (meshwork of *F. exigua* from the Warsaw: 20–21/13–14//22–23/12–13/.)

Discussion.—In their review of *F. exigua* and description of its possible successor, *F. tetratheca* from the Oquirrh formation (Pennsylvanian of Utah) Condra & Elias (1944, p. 133) expressed anticipation "that a variety of *F. exigua* probably will be found in the Chester, with features intermediate between those observed in *F. exigua* from the Salem and those in *F. tetratheca* from the Oquirrh." Such variety is now being found in the Redoak Hollow and possibly will be found also in other beds of Chester age.

FENESTELLA MORROWENSIS Mather
Pl. 44, fig. 5

Fenestella morrowensis MATHER 1915, Denison Univ. Bull. Sci. Lab., vol. 18, p. 115, pl. 4, fig. 11, 11a.

The species was originally described by Mather on abundant material from the Hale formation and Brentwood limestone of the Upper Morrow of western Arkansas, and from beds of the same age in eastern Oklahoma. It is abundant in the Redoak Hollow at localities 1, 3 and 4.

Thanks to the courtesy of Dr. Mather his types have been reexamined, so as to determine the internal structure of the species established by him on external features only. The re-examination yielded the following additional data for *F. morrowensis:* carina carries stout round nodes, about 10 per 5 mm., and between these larger nodes there appear occasionally smaller nodes, usually one between each two larger nodes. Mather's description of the "small elongated nodes . . . at intervals of about .5 mm." apparently refers to the larger nodes of the present description. Outline of zooecial chamber is pentagonal.

The specimens from the Redoak Hollow are in fair agreement with Mather's species, but display certain variability of measurements, which may be expressed in the following summarized formula.

Meshwork formula: 15–20/10–12.5//18–24/6–15, with $3\frac{1}{2}$ to 4 zooecia per fenestrule. (Remeasured formula of the holotype: 15–17/11–11.5//18, with $3\frac{1}{2}$ zooecia per fenestrule).

Outline of zooecial chamber pentagonal to nearly triangular. Reverse is coarsely grooved, and ridges between the grooves finely serrated. Dissepiments flush with branches on reverse where they are faintly grooved, and somewhat depressed on obverse where they are wider and coarsely grooved. Sides of branches and the short spaces between the apertures are also longitudinally grooved. Apertures are round to somewhat oval, with prominent peristome, spaced in average $\frac{1}{2}$ of their diameter part.

FENESTELLA OVATIPORA Elias, n. sp.
Pl. 44, fig. 7

Two fragments, apparently belonging to the same zoarium, have been recovered in close proximity to each other, and judging by the moderate rate of bifurcation of the branches they seem to belong in the mature part of a fan-shaped growth form.

In spite of their large size the apertures are wholly confined within the moderately broad (about 4 mm.) branches, which are about $1\frac{1}{2}$ as wide as the fenestrules. Very low and narrow peristomes practically flush with the highly inclined slopes of the dome-like obverse of the branches, so that the apertures face fenestrules at an angle of about 45°. Carina rises prominently above the slopes and the apertures, and is about .1 mm. wide. Carinal nodes are stout but low, usually spaced as widely as the dissepiments or at a slightly less distance, frequently occurring opposite the dissepiments. Dissepiments are short, coarsely striated on both observe and reverse, much below the carina on obverse, flush with the branches on reverse. Reverse of branches distinctly

grooved, the rounded ridges between the grooves gently tuberculate. Fenestrules narrowly rectangular.

Zooecial chamber pentagonal at the base, its basal posterior slightly overlapping the anterior of the chamber behind it; under this overlap the frontal wall of the latter chamber curves antero-laterally and forms the front of the short and wide vestibulum. There is no trace of either lower or upper hemisepta. Branches expand before each sharp-angled bifurcation, and below each point of bifurcation a few additional chambers are added for a distance nearly as long as a fenestrule. This produces three and four rows of chambers and apertures just below each bifurcation. The branches above the points of bifurcations are narrower than their normal width.

Meshwork formula: 18–19/10–10/5//18–19/5–8.

Discussion.—*F. ovatipora* has a slightly coarser meshwork than that in *F. morrowensis:* 16–18/10.5–11//18–23/6–15. *F. ovatipora* differs from the latter by the unusually large and oval apertures and more prominent carina with fewer nodes. There seem to be no other species of *Fenestella* with apertures so large and oval so that no intervals of the surface are left between them on the obverse. Only the apertures of *Drymotrypa cisseis* (Hall) from the Lower Helderberg (basal Devonian) of New York are reminiscent of those in *Fenestella ovatipora.*

FENESTELLA cf. F. FRUTEX M'Coy
Pl. 43, fig. 12

Fenestella frutex M'COY, 1844, Synopsis . . . Carboniferous Limestone fossils of Ireland; p. 201; pl. 28, fig. 10.

Because of available British material which is identifiable with *Fenestella frutex* M'Coy, this species can be compared to two small fragments collected. It has a conspicuously trapezoid shaped zooecial chamber, a feature generally characteristic for much later Carboniferous and Permian fenestellids, but which is observable on the British material at hand. This is not previously known for this species.

Rapidly spreading branching indicates proximal position of the fragment in a zoarium that could have been as small as M'Coy's zoarium from Ireland.

Branches slightly narrower than fenestrules; carina wide and prominent, with hardly noticeable elevations, and which are somewhat less numerous than apertures. Apertures average 3 per fenestrule; little variation of this number. Dissepiments much below level of carina.

Meshwork formula-22/15//22–23/19–20.

Discussion.—These dimensions are comparable to those of *F. paradisensis,* but shape of zooecial chamber and profile of branches are strikingly different in the two species. *F. frutex* could have evolved from *F. exigua* Ulrich from the Warsaw (Ulrich, 1890, p. 545, pl. 51, fig. 1,1a) and the Spergen (Cumings, 1906, p. 1278, pl. 28, fig. 3,3a), which differ in having fewer (12 to 14) fenestrules per 10 mm., and no tendency toward stabilization of apertures within them.

The British representatives of *F. frutex* under study have somewhat smaller number of zooecia per 5 mm., from 18 to 21, and number of fenestrules per 10 mm., 13½ to 15. A slab with this species comes from High Blantyre, Scotland, and according to Dr. Currie (communication of 1952) belongs to the Mid and Main Hosie limestone at the top of the Lower Limestone Group, now placed by her at the base of the lower Namurian (E_1), or possibly at the top of the upper Viséan (P_2). In another slab from this same Scottish locality is a good example of American species *Fenestella serratula* Ulrich, with meshwork 25–28/20–23//25–27/22–23 similar to that in *F. serratula* from the Warsaw, as described by Condra & Elias (1944, p. 72–74; pl. 13, fig. 6–8).

(Group of *Fenestella veneris*)
FENESTELLA cf. F. CHESTERENSIS Condra & Elias
Pl. 43, fig. 6; Pl. 45, fig. 3

Fenestella multispinosa var. *chesterensis* CONDRA & ELIAS 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 110–112; pl. 35, fig. 1–4.

The form from the Redoak Hollow is closely related to *F. stocktonensis* of the Des Moines and *F. multispinosa* var. *chesterensis* of the Chester, but is closer to the latter in the number of fenestrules, and

also in the larger width of the branches. The apertures are located entirely within them, without protruding into the fenestrules. In *F. stocktonensis*, on the other hand, the apertures protrude into the fenestrules. The form from the Redoak Hollow differs from both discussed forms in having slightly larger number of zooecia per fenestrule and fewer fenestrules per given space, and the well developed carina carries prominent nodes. It has a pentagonal-shaped zooecial chamber, and its branches are wider than fenestrules as in *chesterensis*.

Meshwork formula (based on four fragmentary specimens): 15–20/12.5–15//20–25/14–20; with 3 to 4 zooecia per fenestrule.

(Group of *Fenestella retiformis*)

FENESTELLA SERRATULA Ulrich

Pl. 45, Fig. 2; Pl. 46, Fig. 7–9; Pl. 48, Fig. 1

Fenestella serratula ULRICH 1890 [part], Ill. Geol. Surv., vol. 8, p. 544–545, pl. 50, fig. 5–5c. CUMINGS, 1906 [part], Ind. Dept. Geol. Nat. Res., 30th Ann. Rept., p. 1280, pl. 30, fig. 2–2c only. CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 72–76, pl. 13, fig. 6–8; pl. 21, fig. 4,5; pl. 36, fig. 3.

The specimen from localities 1 and 3 are typical (Warsaw) examples of *F. serratula*.

The details observable in the form from the Redoak Hollow and of value are as follows: apertures are circular, with well elevated perisome and occasionally preserved opercula, which are gently convex upwardly and are marked by small central depression. Spaces between apertures are smaller than their diameter and are occasionally faintly longitudinally grooved. Dissepiments are only slightly depressed on obverse and reverse, sharply grooved longitudinally on obverse and slightly grooved on reverse. Branches are also slightly grooved on reverse, with faint tubercles along the crests between the grooves. Outline of zooecial chamber pentagonal, and there are faint longitudinal grooves on the surface of the base of the zooecial molds.

Bifurcation of branches abrupt, and no third row of zooecia added below the points of bifurcation.

Meshwork formula: 24–27/21–24//27–28/26–28, with $2\frac{1}{2}$ to $2\frac{3}{4}$ zooecia per fenestrule.

FENESTELLA CUMINGSI Condra & Elias

Pl. 43, fig. 3–5; Pl. 44, fig. 2; Pl. 45, fig. 1; Pl. 49, fig. 2

Fenestella cumingsi CONDRA & ELIAS, 1944, Geol. Soc. Amer., Spec. Paper No. 53, p. 103–104, pl. 10, fig. 46; pl. 21, fig. 6; table 83.

The largest and best preserved specimen of *F. cumingsi* 10 mm. long and 8 mm. wide was recovered from the material collected at locality 4, and in contrast with other specimens of bryozoa from the same locality, has most of its calcareous shell preserved. Its finest structural details are best observed on their impressions in form of external and internal molds. The specimen is a rapidly expanding initial part of a somewhat curved fan-shaped zoarium; obverse is slightly concave. Branches are as wide as fenestrules, dissepiments $\frac{1}{3}$ to $\frac{1}{2}$ as wide as branches, depressed on obverse and reverse, and faintly grooved. Reverse of branches with more distinct, narrow grooves. Dome-shaped obverse of branches with low and narrow carina at top, ornamented with moderately prominent nodes, and with large circular to slightly oval apertures on each flank of a dome. Apertures with prominent peristomes, spaced slightly less than their diameter apart. Outline of zooecial chamber pentagonal.

The most important of the several fragments of zoaria recovered from the Redoak Hollow is that (Pl. 11, fig. 2) which serves as base of the two paired screws of *Archimedes meekanoides*. The part of the zoarium supporting the pair of *Archimedes* shafts is about 10 mm. long and 9 mm. wide, and is broadly curved backwards, so that the basal parts of the ascending *Archimedes* shafts are gradually rising in front of its lateral edges.

The development of the two shafts of *Archimedes* causes some deflection of the coarse striae of the reverse of the *Fenestella* toward its left and right edges correspondingly, but does not affect the spacing of the elements of its meshwork. A peculiar swelling and fusing of some zoecial chambers into longer units (pl. 49, fig. 2a) apparently has something to do with the development of the sturdy *Archimedes* shafts and zoarial coiling around them.

The branches of the meshwork are occa-

sionally symmetrically bifurcating, as they spread out moderately thus indicating an early mature part of a fan-shaped zoarium. The chamber is pentagonal and there are $2\frac{1}{2}$ to $2\frac{3}{4}$ zooecia per fenestrule.

Meshwork formula: 20/15–16//21/14. Measurement of other fragments gave the following formula: 17–22/16–19//21–25/17–20.

Discussion.—The meshwork in the Redoak Hollow specimens is only in part within the variability of the type of *F. cumingsi* Condra & Elias from the Chester, which is 16–25/16–20//22–25/25–26, showing a somewhat coarser meshwork, and especially much more distant distribution of the carinal nodes. The meshwork of *F. cumingsi* from the Redoak Hollow is nearer to that of this species that come from the upper Des Moines at Stockton, Utah and on which Condra & Elias measured the following formula: 17–21/14–17//22–25/13–15. This indicates a still coarser zoarium than that from the Redoak Hollow.

(Group of *Fenestella mimica*)
FENESTELLA TENAX Ulrich
Pl. 44, fig. 1; Pl. 48, fig. 6

Fenestella tenax, ULRICH 1890, Ill. Geol. Surv., vol. 8, p. 546–547; pl. 61, fig. 2a–2c (not fig. 2d, var. from Chester). CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 99–102; pl. 21, fig. 1–3.

The largest fragment of zoarium (from locality 4) is considerably curved, the upper part turning to a plane about 90° different from the lower part, the curvature being convex on the obverse. Within this zoarium there is also a sharp change in the direction of the branches, all branches on the right side of the fragment turning abruptly at about 45° to 60° from the general direction of the subparallel branches on the left side of the fragment.

Other features of the form from the Redoak Hollow are typical for *F. tenax*. Branches average about as wide to wider than fenestrules; zooecia number about two per fenestrule but their position in relation to the dissepiments is not stablized. Carinal nodes inconspicuous and the number variable, tending to be about the same as the number of zooecia; outline of zooecial chamber triangular to pentagonal.

The following are the measurements of the meshwork:

F. tenax, locality 1:
28–29/27//30/30
F. tenax, locality 4:
27–30/25–30//25–30/25–30

Discussion.—The study of variability within the meshwork of several zoaria from the Warsaw and the Chester of Illinois and the Oquirrh of Utah, enabled Condra & Elias to restrict Ulrich's species to the zoaria with meshwork as follows:

F. tenax from Oquirrh:
24–35/28–29//29–30/20–30
F. tenax from Chester:
24–35/25–30//25–31/27–38
F. tenax from Warsaw:
28–30/28–29//28–29/30–31

By comparison with the formulas established for this species by Condra & Elias, the zoaria from the Redoak Hollow are nearest to those from the Chester. *F. tenax* changed but little through considerable stretch of geological time, its zoarium remaining widely variable as the formulas just quoted indicate. Hence this species of *Fenestella* is of but moderate stratigraphic use.

(Group of *Fenestella spinulosa*)
FENESTELLA RARA Elias, n. sp.
Pl. 48, fig. 5

The type is a fragment of the basal part of zoarium, 3 mm. long and 2 mm. wide. It apparently represents one side of its basal part, with five successive subparallel lateral branches given off of a central branch at about 50°–60°. Bifurcation of branches is frequent. A straight slender spiniferous branch grows from the lowest lateral branch downwards at 90° to the branch and in the plane of the zoarium. *F. rara* has branches with a single row of sharp, well developed nodes, which are connected by a very thin and low carina. Dissepiments are narrow, depressed on obverse and reverse, and ornamented by a few longitudinal grooves. Every other zooecial aperature is located at the base of a dissepiment or very near it. Outline of zooecial chamber is sharply triangular to trapezoidal.

Meshwork formula: 23–28/22–23//22–23/abt. 25.

Discussion.—Among the multitude of known Carboniferous species of *Fenestella* there are very few that have zoaria with delicate branches which measure only half the width of fenestrules or less, and only one among these, *F. perminuta* Ulrich, which contains two zooecia per fenestrule, is thus comparable to the new species *F. rara* from the Redoak Hollow. *F. rara* has much smaller meshwork, though its branches are slightly wider than those in *F. perminuta*, so that, unlike the conditions in the latter species, its zooecial apertures do not project into the fenestrules.

(Group of *Fenestella cestriensis*)

This new group is characterized by the presence of inferior hemiseptum that divides the zooecial chamber transversely into sub-equal halves. Other characters are as in *F. veneris* group: parallelogram-like to subpentagonal outline of chamber, long fenestrules with 3 to 5 zooecia per fenestrule, and addition of third row of zooecia below points of bifurcation.

FENESTELLA CESTRIENSIS Ulrich
Pl. 48, fig. 2,3

Fenestella cestriensis ULRICH, 1890, Ill. Geol. Surv., vol. 8, p. 547, pl. 61, fig. 5–5b. NICKLES & BASSLER, 1900, U. S. Geol. Surv. Bull. 173, p. 248.

One large and two smaller fragments of the species have been recovered from the same slab and in close proximity to each other. In all of them, the branches bifurcate frequently and diverge rapidly, the zoarium being a nearly flat fan-shaped growth form. Judging by the largest fragment, its size was more than 1 cm. long and about equally wide.

Fenestrules are elongated, sub-rectangular to sub-elliptical and wider than the branches which gives diffuse appearance to the zoarium, even though the branches are not very narrow (about .3 mm. wide). Inferior hemiseptum cuts across each zooecial chamber closer to the distal than to the proximal end, and, in many chambers, it is very close to the distal end. This feature places the species in the same group with *Fenestella paradisensis*, whose zooecial chamber has the same kind of hemiseptum. Outline of zooecial chamber is somewhat variable, from parallelogram-like, with its long sides parallel to the branch, and the short sides inclined distad from the central axis of the branch—to pentagonal, when the inner long side of parallelogram becomes angular through development of a fifth, very wide angle. Reverse of the branches is gently, longitudinally grooved. Elliptical shape of the fenestrules is caused by the combination of the frequent bifurcation and slight lateral undulation of the branches which results also in comparatively short dissepiments. Dissepiments are flush with branches and about as wide, and are ornamented by a narrow but distinct medial carina. Obverse of branches is smooth, with poorly developed carina, but with quite distinct, though low nodes. Apertures are large, circular, less than the width of their diameter apart, with sharply elevated but very narrow rim, and gently concave opercula. Reverse of branches coarsely grooved; dissepiment on reverse less coarsely grooved, and with a narrow carina in the middle.

At a distance of a space equal to about two zooecia below each bifurcation, the branches increase their width rapidly by development of third and fourth rows of zooecia. The additional two rows are added laterally, to the left in the left half of the symmetrical zoarium, and to the right in its right half. Toward the lateral edges of the zoarium, the bifurcation of branches becomes more lateral, resembling very closely the type of bifurcation in *Septopora* rather than that in typical *Fenestella*.

Meshwork formula: 15/9//20–21/abt. 18, with 4½ to 5 zooecia per fenestrule. In the basal part of the zoarium, where the two smaller fragments apparently belong, it is slightly more variable: 15–18/8–10//20–22/12–14, with 4 to 5 zooecia per fenestrule. The formula of the original material described by Ulrich is 17–20/10//21–22/?.

Discussion.—*F. cestriensis* can be differentiated from the other species that possess hemisepta. It differs from *F. paradisensis* by its much coarser meshwork and larger number of apertures per fenestrule. *Fenestella inaequalis* Ulrich, which comes from the Pennsylvanian of Sangamon County, Illinois, resembles *F. cestriensis* greatly in having similar variability of fenestrules and about same meshwork

formula. However, *F. cestriensis* differs in having much larger and more distantly spaced carinal nodes. In *F. inaequalis* the nodes are very small and densely spaced, about 5 nodes per 1 mm. *F. cestriensis* has wider dissepiments, and these are carinate. In *F. inaequalis* the dissepiments average only ½ the width of the branches and are said to be rounded. Internally the zooecial chamber of *F. inaequalis* has more distinctly pentagonal outline of zooecial chamber (Ulrich, 1890, pl. 54, figs. 4,4a). *F. inaequalis* has similar addition of third and fourth rows of the zooecia below bifurcation.

Phylogenetically, *F. cestriensis* seems to have been evolved from a common stock with *F. paradisensis*, and eventually gave rise to the Pennsylvanian species *F. inaequalis*. The evolutionary trend, as reflected by the measurements of the discussed species of *Fenestella*, is toward more distant spacing of zooecia in more advanced *F. inaequalis*, while the number of carinal nodes becomes greatly increased. The reverse of the zoarium also has changed from being smooth with few large scattered nodes in *F. cestriensis*, to a condition covered with grooves, the crests between them being serrate in *F. inaequalis*.

FENESTELLA PARADISENSIS Condra & Elias
Pl. 43, fig. 9

Fenestella paradisensis CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 107–108, pl. 22, fig. 3,4.

Fenestella paradisensis was established by Condra & Elias on only one fragment whose obverse is firmly embedded in sandy limestone, thus rendering study of its details practically impossible. The material from the Redoak Hollow, which can be safely referred to this species, is not very rare, and fine preservation of its molds permits convenient observation in detail of reverse, obverse, and of the internal structure. Two fragments from locality No. 1 correspond well to the holotype in both internal structure and meshwork formula, while other specimens are sufficiently distinct to be differentiated as a new variety *ardmorensis*.

The two fragments of typical *F. paradisensis* furnish accurate information about the obverse of this species for the first time, and these new data seem in harmony with what can be dimly discerned in the one immersed in the sand obverse of the holotype. In the obverse from the Redoak Hollow there is no clearly defined carina, and its position is indicated by a single row of nodes, which are variable in size and spacing. They vary from small to fairly prominent, and are spaced at distances from slightly larger than that between zooecial apertures, to about twice that amount. Apertures are circular, with fairly prominent peristomes, slightly more than the width of their diameter apart. Outline of zooecial chamber sub-rectangular, with somewhat inclined transverse walls, and with slight tendency toward a pentagonal shape. In one fragment the lower hemiseptum divides the chambers into nearly equal halves, just as in the most typical portion of the holotype from the Paradise formation. In a few of these chambers there can be detected a second, smaller hemiseptum, that

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EXPLANATION OF PLATE 47

FIG. *1–5—Archimedes pitkinensis*, n. sp. *1,2*, Holotype from Pitkin limestone broken into lower and upper halves, ×1. *3*, Expanse of the lowermost volution of holotype, ×10. *4,5*, External mold from Redoak Hollow, ×3; and molds of its flange, ×10.

6,7—Archimedes ardmorensis, n. sp. *6*, Holotype from Kinkaid limestone, 2 mi. east of Lickcreek, Illinois, ×2. *7*, Lower part of its expanse, ×20.

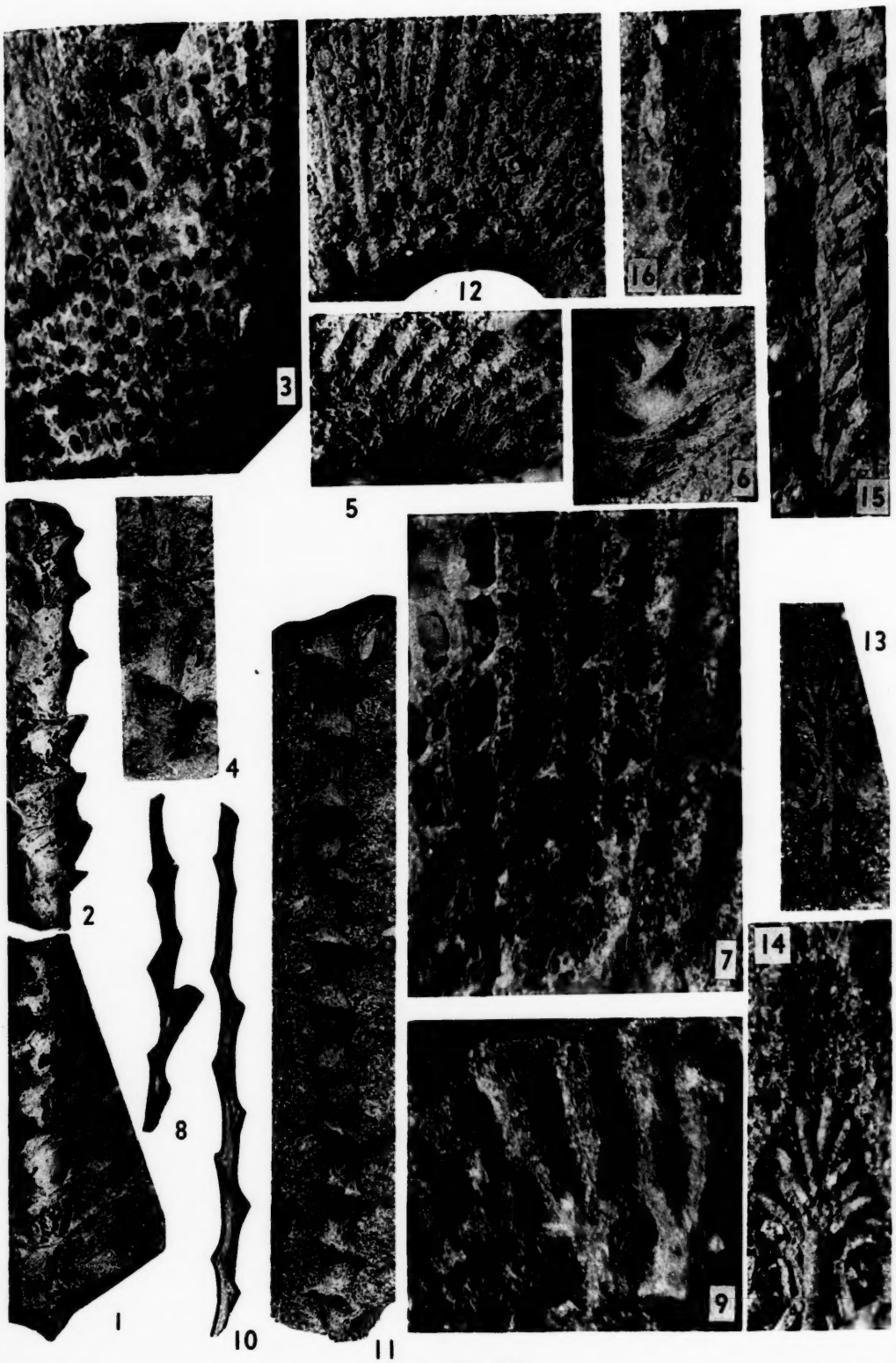
8–10—Archimedes rigidus, n. sp. *8,9*, Holotype and cotype from Clore limestone, 2 mi. south of Chester, Illinois, ×2; and its expanse, ×20. *10*, Cotype, Clore limestone, 2 mi. south of Chester, Illinois, ×2.

11,12—Archimedes pseudoswallovanus, n. sp. Holotype (mold), ×2; and basal part of its expanse, ×10, from Redoak Hollow.

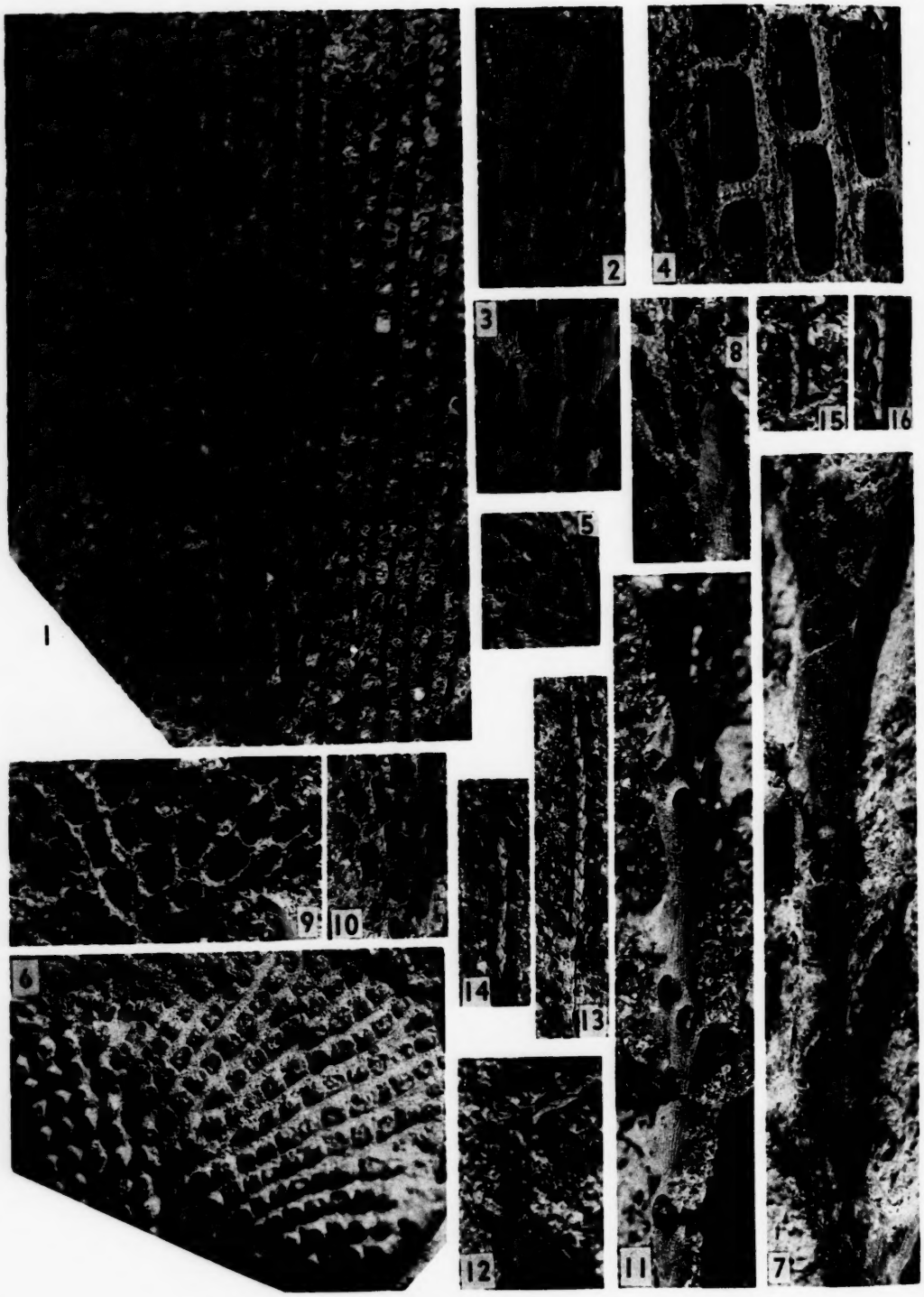
13,14—Rhabdomeson (Rhombopora) rogersi, n. sp. Holotype from Redoak Hollow, ×10 and ×20.

15—Rhabdomeson (Rhombopora) foerstei, n. sp. Cotype (mold) from Redoak Hollow, with partly preserved calcareous axial tube, ×20.

16—Rhabdomeson (Rhombopora) ulrichi, n. sp. Cotype (mold) from Redoak Hollow, with partly preserved calcareous cortical region, ×20.



Maxim K. Elias



Maxim K. Elias

cuts off a very small triangle from the outer posterior sharp angle of a chamber. In another fragment, a single lower hemisptum is located very near the posterior end of the chamber and is parallel to it. The same kind of position and orientation of lower hemiseptum is noticeable in the right end of the enlarged photograph of the holotype (Condra & Elias, 1944, pl. 22, fig. 4). Surface between zooecial apertures smooth. Dissepiments flush with the branches on obverse, and are coarsely grooved. The reverse of branches is also coarsely grooved, and the crests of the folds between the grooves are tuberculate. Dissepiments are flush with the branches on the reverse, and faintly grooved.

Meshwork formula of the three fragments is correspondingly 15–17/14–14.5//21–23/15–16, 16/15//22–23/15, and 20/14//20/14, with 3 to 3½ zooecia per fenestrule.

FENESTELLA PARADISENSIS var. ARDMORENSIS Elias, n. var.
Pl. 44, fig. 3

By *ardmorensis* is designated a new variety of *F. paradisensis*, which is distinguished from the typical species by larger fenestrules, with 2½ to 4 zooecia per fenestrule, and the reverse being differently ornamented; roughly tuberculate with smooth surface between the tubercles. The variety has been collected from locality No. 3.

Meshwork formula: 18–19/12–13.5//20–22/12–15.

Discussion.—There are very few species of *Fenestella* that have lower hemisepta, hence its presence is very characteristic of a species. The nearest to *F. paradisensis* and its variety *ardmorensis* is *F. inaequalis* Ulrich from the upper Coal Measures of Illinois (Ulrich, 1890, p. 554, pl. 52, fig. 9,9a and pl. 54, fig. 4,4a). It has a lower hemiseptum, not mentioned in the description but shown on Ulrich's sketch (pl. 54, fig. 14). Its reverse is covered by "granulose striae" and it contains about the same number of zooecia per fenestrule, 3 to 4, as in var. *ardmorensis*, and as in *F. paradisensis*. It differs from both by fewer fenestrules and fewer zooecia per same space, that is by coarser meshwork, and also by smaller and more numerous nodes upon its strong carina. Its meshwork formula, composed from Ulrich's measurement is as follows: 16–18/19//18/50.

Genus FENESTEVERTA Elias, n. gen.

The essential features which differentiate *Fenesteverta* from other known genera, may

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EXPLANATION OF PLATE 48

FIG. *1*—*Fenestella serratula* Ulrich. External mold of the obverse of a central part of mature zoarium, with a few molds of zooecial chambers attached (near center of lower half), ×10.

2,3—*Fenestella cestriensis* Ulrich. *2*, Internal molds of zooecial chambers viewed from the reverse, and external mold of the obverse (center of upper part and center of right side), ×10. *3*, External mold of the reverse of the same specimen, ×10.

4—*Polypora debilis*? n. sp. Obverse of the fragment to the reverse of which *Thamniscus erectus*, n. sp., is attached ×10. Peculiar sculpture of the branches and the dissepiments of this fragment suggests considerable alteration of the original structure of *P. debilis*, ×10.

5—*Fenestella rara*, n. sp. Fragmentary holotype: internal mold of zooecial chambers viewed from the reverse, and external mold of the obverse (lower center), ×10.

6—*Fenestella tenax* Ulrich. External mold of the reverse of central and lateral part of a mature zoarium, ×10.

7–9—*Archimedes rigidus*, n. sp. *7*, cotype, from Clore limestone 2 miles SE of Chester, Illinois, ×10. *8,9*, External molds of the rigid shaft with the external molds of the obverse of the attached expanse, ×10.

10—*Archimedes* aff. *A. perminimus* Ulrich. External mold of the shaft and the external mold of the obverse of the attached expanse, ×10.

11—*Archimedes* cf. *A. meekanus* Hall. External mold of a shaft; side view, ×10.

12—*Septopora* cf. *S. pinnata* Ulrich. External mold of the obverse of the main axis, and the inner mold of the zooecial chambers in the lateral branch and the dissepiment (in the upper right corner), ×10.

13–16—*Penniretepora ardmorensis*, n. sp. *13*, Holotype, showing outer mold of the obverse and the inner molds of the zooecial chambers viewed from the reverse, ×10. *14–16*, Inner molds of the zooecial chambers viewed from the reverse. ×10 and ×20 (16).

be formulated in the following generic diagnosis:

Zoarium made of polyporid main branch from one side of which extend fenestellid branches; the whole is twisted into a helicoid, with main branch winding around the axis of coiling, and the obverse facing outward.

The only known species, *Fenesteverta nicklesi* serves as type-species.

Discussion.—The new genus is introduced for the single species which differs from the previously known Fenestrata in two respects: (1) in the arrangement of zooecia along its branches, and (2) in the position of the zooecial apertures in relation to the spiral twist of the zoarium.

At a first glance the new genus looks like an ordinary *Fenestella* (with branches consisting of two rows of zooecia) whose zoarium became twisted in a fashion customary for *Archimedes*. However, the edge of the zoarium, that is nearest to the axis of the spiral twist, shows no encrustation by secondary tissue, and thus is not like the corresponding spirally twisted and encrusted central edge in subgenus *Helicopora* of genus *Archimedes*. The edge in *Fenesteverta*, that became central in the twist, is also thicker than the rest of the zoarium, as in *Helicopora*. This is so not because of secondary encrustation, but because the centralized edge became a branch made of four rows of zooecia instead of two. This is the case in all lateral branches that come out of it. Thus the zoarium in *Fenesteverta* consists of a main polyporid or a *four zooecia* wide branch. Out of one side come fenestellid or *two zooecia* wide lateral branches. Furthermore, the whole zoarium is twisted in a helicoid, much like that in *Archimedes* (and its subgenus *Helicopora*), except that in *Fenesteverta* this twist results in the obverse facing downward and away from the axis of the twist, while in *Archimedes* (and *Helicopora*) the obverse faces upward and toward the axis.

In a memoir on Permian *Fenestella* Elias & Condra (in press) describe a new species, twisted like *Archimedes*, but whose axial edge is not encrusted. In this Permian species the obverse faces upwards and toward the axis of coiling, and there is no differentiation into a main polyporid and lateral fenestellid branches.

FENESTEVERTA NICKLESI Elias, n. sp.
Pl. 43, fig. 7,8

The inner edge of helicoidal growth-form is formed by a polyporid branch that is nearly twice as wide as all lateral fenestellid branches of the meshwork. It is coiled around a geometrical axis, keeping at an even distance of about 1 mm. from it.

Each lateral branch bifurcates within a very short distance from the main branch. The angle of bifurcation is wide, and below each point of bifurcation is added one additional aperture, where ordinarily carinal nodes should be. Lateral branches average as wide as fenestrules. Carina is narrow and sharply defined, ornamented with strong nodes which are almost as wide at their bases as the diameter of the apertures, particularly the nodes below the points of bifurcation. Apertures are smaller than that in most species of *Fenestella*, are furnished with narrow but distinctly elevated peristomes, and are spaced about 1½ times the width of their own diameter apart. The surface of all branches on the obverse and reverse is covered by coarse, deeply cut striae or grooves, which become even coarser on the main (polyporid) branch. Dissepiments average about half the width of branches, and are also grooved longitudinally. Fenestrules are elongate, subrectangular. Most chambers develop distinct lower hemisepta.

Meshwork formula: 20–22/11.5–12//20–22/about 25, and there are usually about 3½ zooecia per fenestrule. In the main polyporid branch the zooecia are more distantly spaced, especially in the longitudinal rows nearest to the inner, non-branching edge, where there are only 10 or 11 apertures per 5 mm.

Discussion.—*F. paradisensis* var. *ardmorensis*, n. var., has nearly the same formula, but *F. nicklesi* differs from it not only in coiled growth form, but also in a less regularly developed lower hemiseptum, more numerous carinal nodes, and strongly grooved surface of branches and dissepiments. Most important difference is the development of a polyporid main branch, which furnishes the inner border of the coiled zoarium of *F. nicklesi*. *Fenestella*, new species, Elias & Condra (in press) from the Wolfcamp series of Glass Mountains, Texas, has a similarly coiled zoarium, but is

more tightly coiled than *F. nicklesi* and has a different meshwork, 15–17/17–18.5//17–18.5/11–18, with two zooecia per fenestrule.

The species is named after the late J. M. Nickles, the senior author of "Synopsis of American fossil Bryozoa," an indispensable summary of Paleozoic bryozoa with the bibliography of living and fossil Bryozoa of the World.

ARCHIMEDES PSEUDOSWALLOVANUS
Elias, n. sp.
Pl. 47, fig. 11,12

The single specimen recovered is a 54 mm. long fragment of a screw with but extremely narrow ragged fringe of expanse attached to its small flange about 7 mm. diameter. Its shaft keeps close to 2 mm. in diameter throughout, and its height of volution averages 4½ mm., occasionally reaching 5 mm., near the base decreasing to 3½ mm.

The measurements of the meshwork made within the narrow flange and the base of the expanse are expressed in the following formula:

22–23/22–23//26–27/?.

This is close to that of *Fenestella serratula* Ulrich, and particularly to that in the Chester examples of this species (Condra & Elias, 1944, p. 73–74).

Discussion.—This is a form with a thick screw much like that in *Archimedes swallovanus* Hall, but with an expanse like *Fenestella serratula*, instead of *F. rectangularis* as in Hall's species. Comparative study of the typical *Archimedes swallovanus* from the middle Chester of Illinois with the similar type screws from the Clore and Kinkaid indicates that true *A. swallovanus* typified by *Fenestella rectangularis* meshwork (Condra & Elias, 1944, p. 131–132, 188–189) does not range above the Menard. The similar screws occurring in the higher Chester have still another type of meshwork, that of *Fenestella chesterensis* Condra & Elias, and therefore belong to another species of *Archimedes*, as yet undescribed. On the other hand true *A. swallovanus* is fairly common in the Pitkin of Arkansas.

ARCHIMEDES ARDMORENSIS Elias, n. sp.
Pl. 47, fig. 6,7; Pl. 49, fig. 4–6

The species was named *ardmorensis* (*nomen nudum*, Elias, 1956, p. 86) as it was found at first in the Redoak Hollow of the Ardmore basin. Subsequently, a much more complete and fully calcareous specimen of this species was discovered at the type-locality of the Kinkaid formation of Illinois, and the latter is here designated the type of the species.

Kinkaid material.—Holotype consists of five volutions with widely (to 40 mm. across) developed expanse. However, the shaft of the lower three volutions is fully and solidly embedded in the matrix, and only the upper two are exposed. Because of the demonstrated rapid decrease in the diameter of the shaft, from 3 mm. below to 1 mm. in the uppermost volution, they certainly belong near top if not to the very top of a screw. The height of each of the two volutions is 3 mm., and the screw is typically mechanical and corkscrew kind, with abruptly expanded and sharply terminated flange that measures 4½ to nearly 6 mm. across.

When in flange and at the very base of expanse the fenestrules are shorter than farther toward the periphery, the meshwork being as follows: 25/15–21//25–26/17–26; the shorter proximal fenestrules with 2¼–2½ zooecia per each, and the longer distal fenestrules with 3–3¼ zooecia per each. Carina narrow and sharp, with elongated nodes. Outline of zooecial chamber pentagonal. Circular apertures spaced the width of their own diameter apart.

Redoak Hollow specimen.—The only specimen consists of two volutions, the upper having narrower shaft than the lower, and an oblique and narrow upward extension indicative of terminus of *Archimedes* screw. The Redoak Hollow specimen too has its expanse preserved but it extends only up to 10 mm. across. Volutions are 3 mm. high; the shaft in the upper volution 1 mm. wide, and the incompletely preserved shaft in the lower volution more than 1 mm. wide. Screw is clearly mechanical and corkscrew kind. Meshwork formula 24–25/19–23 (to 27 at shaft)//26/about 25; longest fenestrules at the periphery, which is probably just at the edge of flange and the base of the expanse. Outline of zooecial chamber triangular to pentagonal.

Discussion.—New species resembles by its

cork-screw character *Archimedes terebriformis* Ulrich, but has smaller height of volutions and different meshwork. It also resembles *A. stoyanowi* but the latter has a flaring instead of mechanical screw.

ARCHIMEDES cf. A. MEEKANUS Hall
Pl. 48, fig. 11; Pl. 49, fig. 7,8,10

Fenestella (*Archimedes*) *meekanus* HALL, 1857, Amer. Assoc. Adv. Sci., Pr., vol. 10, p. 178 (not illustrated).

Archimedes meekanus ULRICH, 1890, Ill. Geol. Surv., vol. 8, p. 578, pl. 63, fig. 4. ULRICH, 1905, U. S. Geol. Surv., Prof. Pap. 36, pl. 4, fig. 9a–9e. MCFARLAN, 1942, Jour. Paleont., vol. 16, p. 438, pl. 65, fig. 18. CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 143–147, pl. 8, fig. 8,9; pl. 29, fig. 15–21.

The examples from the Redoak Hollow are characterized by the graceful, slender, somewhat corkscrew-like shaft, with diameter from .4 to .6 mm., and height of volutions varying from 2.7 to 4 mm. Its expanse is flaring, but with insignificant flange. Meshwork formula was measured on the expanse of two specimens as follows: (1) 20/15–16//22–23/about 16; (2) 17/16//23–24/?; the number of zooecia per fenestrule near 3, and the outline of zooecial chamber pentagonal. These data on the meshwork are not much different from those for the meshwork in *A. meekanus*, as observed by Condra & Elias (1944, p. 143–147): 19–27/14.5–20/20–25/18–22, with 2½ to 3 zooecia per fenestrule and rectangular to sub-pentagonal outline of zooecial chamber, all these data near those in *Fenestella matheri* Condra & Elias.

Another external mold of a screw (pl. 11, fig. 10), which is much like ordinary *Archimedes meekanus*, is questionably referred to this species because its expanse is broken off entirely and therefore its meshwork cannot be observed. Its shaft is about 1.5 mm. in diameter, and its height of volutions varies from 5 mm. below to 4.5 mm. above.

Discussion.—The described examples differ from typical *A. meekanus* only in a smaller average height of volutions (3 to 5 mm. in the types from Illinois), smaller number of carinal nodes, more nearly pentagonal than rectangular outline of zooecial chamber, and a more slender shaft. Hence the form is indicated as *A.* cf. *A. meekanus*, and perhaps should be formally recognized as a variety of *A. meekanus*. It approaches *A.*

EXPLANATION OF PLATE 49

FIG. *1*—*Archimedes distans* Ulrich. External mold of a shaft whose volutions are broken off. ×1.

2—*Archimedes meekanoides* McFarlan. Basal zoarium with *Fenestella cumingsi* meshwork upon which arises a pair of screws, around which the meshwork is coiled, ×2.

3—*Archimedes* cf. *A. sublaxus* Ulrich. External mold of a shaft whose volutions are broken off, ×2.

4–6—*Archimedes ardmorensis*, n. sp., ×10. *4*, External mold of the obverse of an expanse. *5*, External mold of the reverse of an expanse. *6*, External mold of a shaft; side view.

7,8—*Archimedes* cf. *A. meekanus* Hall, ×10. *7*, External mold of a shaft; side view. *8*, External mold of a shaft (side view), within which are preserved internal molds of zooecial chambers (below).

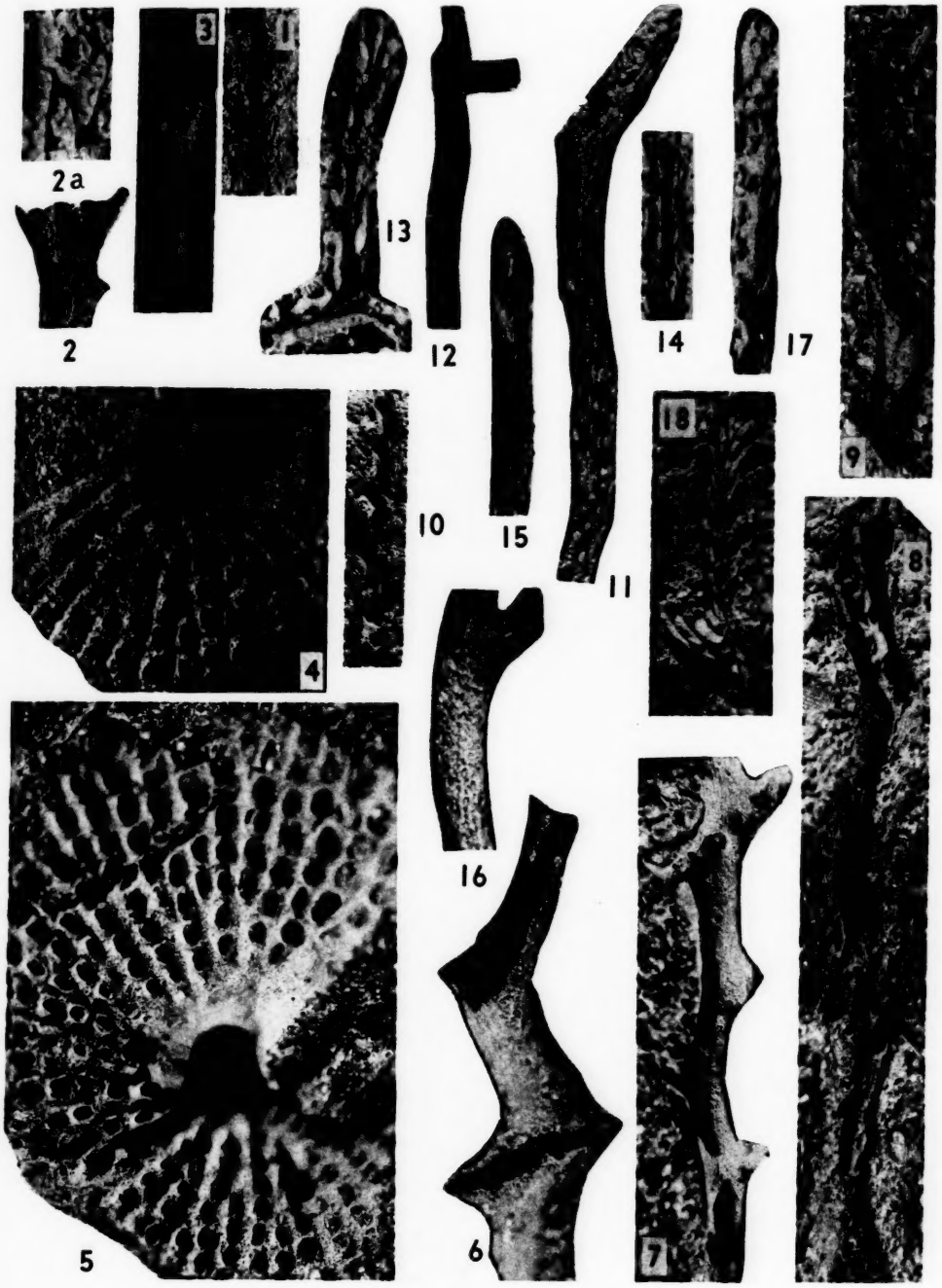
9—*Archimedes* aff. *A. perminimus* Ulrich. External mold of a shaft with a part of adjacent expanse, side view, ×10.

10—*Archimedes* cf. *A. meekanus* Hall. External mold, side view, ×2.

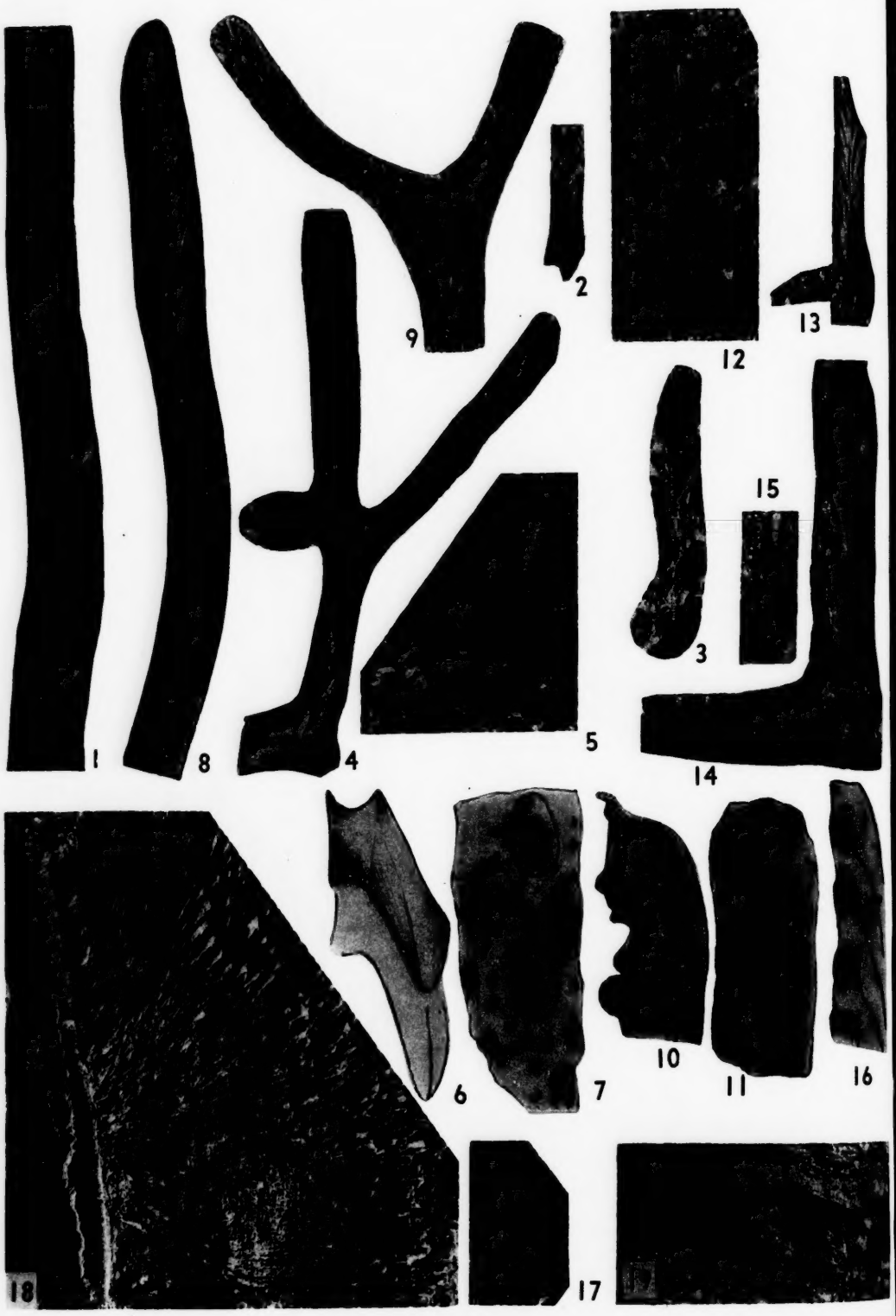
11–15—*Streblotrypa nicklesi* Ulrich. *11*, External mold of typical individual, with branches at an acute angle. A few inner molds of zooecial tubes extend inwards from the apertures, in lower half, ×10. *12*, External mold of primary branch with many molds of zooecial tubes attached to the apertures. To the right is attached a lateral branch at angle of about 90°, ×10. *13*, Primary branch, below, with an axial tube, and a secondary branch, above, without axial tube; attached at an angle of 75°, ×20. *14*, Primary branch, showing axial depression in which axial tube has been lodged, ×10. *15*, Outer mold with numerous molds of zooecial tubes attached to the apertures (above), ×10.

16,17—*Rhabdomeson* (*Rhombopora*) *ulrichi*, n. sp. *16*, Outer view of a specimen with preserved calcareous skeleton, ×10. *17*, Outer mold, with many molds of zooecial tubes attached to the apertures, ×20.

18—*Rhabdomeson* (*Rhombopora*) *foerstei*, n. sp. Holotype, axial sections exposed by longitudinal breaks across zoaria. Primary branch with axial tube, and lateral branch without axial tube, branching off at about 80–85° angle, ×10.



Maxim K. Elias



Maxim K. Elias

fragilis Condra & Elias (1944, p. 127) in the thinness of the shaft, but the latter species has a shorter average height of volutions.

ARCHIMEDES MEEKANOIDES McFarlan
Pl. 49, fig. 2

Archimedes invaginatus var. *meekanoides* McFARLAN, 1942, Jour. Paleont., vol. 16, p. 442, pl. 65, fig. 3–7 (Renault and Paint Creek formations).

Archimedes meekanoides CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 125–217, pl. 10, fig. 4a; pl. 25, fig. 6, table 36 (Chester series, 2 mi. southeast of Chester, Ill.)

The species previously known from the Chester group of Illinois and Kentucky is represented by a rarely found basal part consisting of two paired symmetrical screws growing upon a slightly curved zoarium of *Fenestella*. These paired screws resemble closely the paired screws of *Archimedes distans* from the Chester series of Illinois (Condra & Elias, 1944, pl. 8, fig. 5,6; pl. 25, fig. 3,4).

The coiled shafts of the Redoak Hollow example are only .4 mm. in diameter, which is less than half of the diameter of previously described specimens of *A. meekanoides*, but they all belong to the mature part of the screw, where its shaft invariably attains greatest thickness. The height of volutions in the presently described example is about 5 or 6 mm., which is normal for the species.

The formula of the meshwork, as measured on the basal zoarium, is 20/15–16//21/14, with $2\frac{1}{2}$ to $2\frac{3}{4}$ zooecia per fenestrule. The zooecial chamber has pentagonal outline. These data are typical of both *F. cumingsi* and the expanse of *Archimedes meekanoides*.

Excellent preservation of the internal mold of *F. cumingsi* just below the point where one of the paired screws makes its start, allows an observation of abnormal features in the zooecial chambers. Neighboring zooecia tend to fuse in their slightly smaller basal part, and, in one case, a connecting tube, equal in diameter to the zooecia, connect the zooecia of two neighboring branches, running somewhat diagonally inside the widened connecting dissepiment. This peculiar development, which has been observed in a few other *Archimedes* shafts from the Redoak Hollow, apparently manifests certain organic changes in the zooecia of *Fenestella* that results in coiling of zoarium into an *Archimedes* growth form.

Discussion.—Our example consists of two symmetrical screws whose height of volutions is the same as in *A. distans*, but the meshwork of the basal zoarium (of *Fenestella*), which continues into the revolving

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EXPLANATION OF PLATE 50

FIG. *1–7—Rhabdomeson* (*Rhombopora*) *foerstei*, n. sp. *1*, Outer mold of typical secondary branch with molds of zooecial tubes in lower half, ×20. *2*, Fragment of primary branch with small and somewhat flexuose axial tube, ×10. *3*, Cross-section of primary branch, with sub-circular axial tube, and longitudinal section of a lateral branch, attached at about 90° angle, ×10. *4*, Primary branch with axial tube to which is attached repeatedly branching system with an ovicell ×10. *5*, Detail of the same specimen as in *4*, at the departure of the lateral branch from the primary branch, ×20. *6*, Molds of typical zooecial tubes in secondary branch, ×50. *7*, Typical exterior of secondary branch, ×50.

8–11—Rhabdomeson (*Rhombopora*) *ulrichi*, n. sp. *8*, Outer mold with numerous molds of zooecial tubes attached to the apertures in upper part, ×20. *9*, Outer mold showing method of branching. A few molds of zooecial tubes are attached to the apertures, ×10. *10*, Longitudinal section to show shape of zooecial chamber and its widely perforated diaphragms. Position of megacanthopores directly above tori, ×50 and ×100. *11*, Typical exterior of secondary branch, showing zooecial apertures, mesopores, megacanthopores, and nodes, ×50.

12–16—Rhabdomeson (*Rhombopora*) *rogersi*, n. sp. *12,13*, Holotype, opposite sides of the same specimen, the axial tube of the primary branch broken across, so that each side of the specimen has a part of the tube. Secondary branch is attached at about 90° to the main axis, ×10. *14*, Same as 13, ×20. *15*, Cross-section view of axial tube, ×20. *16*, Longitudinal section to show shape of zooecial chambers, superior and inferior hemisepta, and megacanthopores, ×50.

17–18—Stenocladia? *bassleri*, n. sp., on *Enchostoma*? cf. *E. bicarinatum 17*, Holotype, naturally split along the plane of bifoliation, ×1. *18*, Detail, ×20.

19—Tabulipora cf. *T. tuberculata* Prout, encrusting compressed tube of unknown nature, ×10.

flange and expanse of the screws, is decidedly that of *Fenestella cumingsi* Condra & Elias (1944, p. 103–104, pl. 10, fig. 4b; pl. 21, fig. 6). The holotype of this species of *Fenestella* was found in association with *Archimedes meekanoides*, though probable growth of the latter upon the former can only be inferred as the base of the *Archimedes* being broken off.

ARCHIMEDES aff. A. PERMINIMUS Ulrich
Pl. 48, fig. 10; Pl. 49, fig. 9

The single, well preserved specimen is an external mold of a very delicate helicoid, whose measurements are intermediate between those of *A. perminimus* Ulrich and *A. fragilis* Condra & Elias. Its shaft is .5 mm. in diameter, and height of volutions 2.5 mm. Its coiling is of cork-screw type, and, in this respect, it is nearer to *A. perminimus*, being perhaps a more mature or more distant part of the screw, if the holotype represented more nearly basal part of the same; or the Redoak Hollow form may be an advanced transient (or waagenon) of *A. perminimus*.

The expanse is well preserved, and therefore allows complete observation of its meshwork, whose formula is 18–19/15//19–20/15. There are, in average, 2½ zooecia per fenestrule, and the outline of the zooecial chamber is triangular to pentagonal. All these features are typical for *Fenestella cumingsi*, which is the meshwork in both *Archimedes perminimus* and *A. fragilis*.

ARCHIMEDES PITKINENSIS Elias n. sp.
Pl. 47, fig. 1–5

This is the most massive among the species of *Archimedes* in the Redoak Hollow. It is named *pitkinensis* because an identical form has been collected by C. L. Foster from the Pitkin limestone about 8 miles northeast of Ft. Gibson, Oklahoma and donated to the Nebraska Geological Survey. The latter is much more nearly complete and fully calcareous and hence is designated the holotype and described here together with the identical Redoak Hollow material.

The 125 mm. long fragment from the Pitkin limestone indicates that the species, was probably at least 150–160 mm. long, as per morphologic comparison with very similar *A. magnus* Condra & Elias (1944, p. 154, pl. 32, fig. 2–9). Considerable variability of height of volutions and width of shaft is noticeable, with an apparent correlation between these characters: the longer the volution height, the narrower the shaft. The shortest, 3.5 mm. volutions with the widest, 8 mm., shaft are in the middle part of the holotype, while the longest, 9 mm. volution with the narrowest, 4 mm. shaft, is located in its upper part. Next above it, the shaft becomes somewhat wider and the volution shorter.

Volutions are cup-shaped and widely flaring when short, but change to sub-wineglass shape with basal flare nearly equal to a moderate upper flare in the longest volutions.

Expanse starts with only a slight basal incrustation from abruptly accuminate edges of flange, whose width is from 10 mm. in longest volution, to 12–13 mm. in shortest volutions. The largest preserved part of the expanse is attached to the right side of the lowest volution of the holotype. Grinding and etching of a portion of its exposed (13 mm. long) reverse shows elongate pentagonal to triangular outline of the base of the zooecial chamber. An adjacent broken off part of the expanse has left a fairly sharp impression in the rock that permits observation of the spacing of quite strong though short carinal nodes. The measured data can be expressed in a meshwork formula.

25–30/21 (near top)–24//25–29/40, which is close to that of *Fenestella serratula* Ulrich, sensu stricto (Warsaw examples). Number of zooecia per fenestrules varies from 2½ to 2¾. Zooecial apertures circular, with narrow peristome, slightly more than their diameter apart.

Occurrence.—Pitkin limestone (upper), sec. 25, T. 16 N., R. 19 W., Oklahoma.

The external mold of the Redoak Hollow specimen, 18 mm. long, consists of slightly more than two volutions, the lower cup-shaped, 4 mm. wide and 6½ mm. high, and the upper wineglass-like, 3 mm. wide and 8 mm. high, and the flange up to 6 mm. wide. Imprint on the rock from the upper side of small part of flange at the base of lower volution permits measurement of the following meshwork: 21–25/19–22//25/?, and shows that the zooecial chamber has a sub-pentagonal outline.

These data compare reasonably well with those of the Pitkin holotype, especially the shape and character of the variability of the volutions.

Discussion.—In size and shape of volutions, the new species is almost like *Archimedes magnus* Condra & Elias (1944, p. 154–157, pl. 6 fig. 1, pl. 32, fig. 2–9). However, the flange in *A. magnus* is more flaring and correspondingly of larger width, 4 to 18 mm., and its meshwork is quite different, 20–29/14–17//22–25/27–35, with rectangular shape of zooecial chamber, thus being close to that of *Fenestella matheri* Condra & Elias.

ARCHIMEDES DISTANS Ulrich
Pl. 49, fig. 1

Archimedes distans ULRICH, 1890, Ill. Geol. Surv., vol. 8, p. 578–579, pl. 63, fig. 9–9b. CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Pap. No. 53, p. 117–120; pl. 8, fig. 5,6; pl. 9; pl. 25, fig. 14.
Archimedes meekanus var. *distans* MCFARLAN, 1941, Tab. 1, p. 438–439; pl. 2.

Several molds of fragmentary screws from the Redoak Hollow, the largest, 20 mm. long, apparently belongs to this species. It was possible to measure approximate length of its fenestrules. which indicates about 22 fenestrules per 10 mm., or well within the range of variability for this element (Condra & Elias, 1944, tab. 31, p. 119). Breaking across a flange of a smaller fragment showed the occurrence of 2½ zooecial apertures per fenestrule, which is characteristic for the meshwork of *A. distans*, and a slightly larger number of carinal nodes, also a characteristic feature for this species.

Another long fragment has both the meshwork and the screw typical of *A. distans* but its shaft is thicker, nearly 2 mm. across. The meshwork preserved only in the narrow flange and slightly beyond it measures 26/22–23//24–25/?.

The measurements for the screws of the three described specimens are as follows:

	Diameter mm.	Height of Volutions, mm.
Larger fragment (20 mm. long):	1.2	3.5 to 5.0
Smaller fragment (11 mm. long):	.8 to 1.2	4.5
Fragment with thicker shaft (24 mm. long)	1.9	5.5 to 6.0

ARCHIMEDES RIGIDUS Elias, n. sp.
Pl. 47, fig. 8–10; Pl. 48, fig. 7–9

Clore examples.—Holotype is well preserved fragment 26 mm. long, consisting of nearly four volutions whose height varies from 5½ to 6 mm., and width of shaft is .7 mm. Slightly flaring flange is 1.5–2 mm. across. A longer specimen with no expanse preserved has the same diameter of shaft and its five volutions average 7½ mm. high.

Meshwork measured on a preserved part of expanse in the holotype is 18–20/13//22/18–20, with 3–3½ apertures per fenestrule, and pentagonal outline of zooecial chamber at the base; apertures with circular peristome, spaced own diameter apart.

Occurrence.—On hill about 2 mi. south of Chester, Illinois.

Redoak Hollow examples.—Molds of only two small fragments of this species have been originally recovered, but their features were so strikingly different from those of all known species of *Archimedes* that their differentiation as a new species seemed desirable and justifiable. Most interesting is its perfectly straight columnar shaft with not a trace of flange at the base of the expanse that winds around it at an acute angle.

The best preserved fragment is 35 mm. long and has a uniform .6 mm. wide shaft, with surface distinctly longitudinally striated. Judging by the rate of winding of the expanse the height of volutions must have been about 6 or 7 mm. The expanse departs out of the shaft at an angle of about 35°, the branches of its meshwork are straight and not encrusted even at the point of the departure from the shaft. The whole of the winding meshwork is quite free from encrusting tissue and its fenestrules are as open as in ordinary fronds of *Fenestella*. In another example height of volutions is 6–6½ mm. and width of shaft 1 mm.

Meshwork is 20–22/12–13//21–23/18, with slightly over 3 zooecia per fenestrule. Outline of zooecial chamber is pentagonal at base. Apertures are round, comparatively small, spaced about 1½ the width of their diameter apart. Dissepiments spaced with slight irregularity, striated on obverse. Carina slightly indicated to none, but carinal nodes are usually developed, though small.

Discussion.—*A. rigidus* differs from similar screws of *A. distans* Ulrich, by much larger height of volutions and by quite different meshwork.

ARCHIMEDES cf. A. SUBLAXUS Ulrich
Pl. 49, fig. 3

Archimedes sublaxus ULRICH, 1890, Ill. Geol. Surv., vol. 8, p. 568, 579, pl. 63, fig. 14. Mc-

FARLAN, 1942, Jour. Paleont., vol. 16, p. 433. CONDRA & ELIAS, 1944, Geol. Soc. Amer. Spec. Paper No. 53, p. 157–159; pl. 8, fig. 7; pl. 33, fig. 5–7.

A single outer mold of a coiled shaft, from which all expanse is broken off evenly around the flanges, is questionably referred to *Archimedes sublaxus* because it is impossible to verify this identification by the meshwork which is not preserved. There is no other type of coiled shaft among all known species of *Archimedes* which would approach that of *A. sublaxus*. The specimen from the Redoak Hollow measures as follows: diameter of shaft about 2 mm.; diameter of flange about 7 mm.; cork-screw off-set about 1.5 mm.; height of volutions 12 mm. The corresponding dimensions of *A. sublaxus* are as follows: diameter of shaft 1.1 to 1.5 mm.; diameter of flange 2 to 4 mm.; cork-screw off-set 1.5 to 2 mm.; height of volutions about 11 mm. The observed differences in the two sets of measurements may be ascribed to greater maturity of the specimen from the Redoak Hollow. The previously known single example of *A. sublaxus*, in form of paired screws, represents the early part of its zoarium only. The specimen from the Redoak Hollow could also be regarded as a variety of *A. sublaxus*, or a new species characterized by the above quoted measurements.

POLYPORA (POLYPORELLA) OVICELLATA Elias, n. sp.
Pl. 46, fig. 1–3

Holotype is a complete or nearly complete zoarium of this new species, both external and internal molds showing finest structural details. The zoarium starts as a thin disk about 2 mm. in diameter, from which rise vertically at least five (but probably 7 or 8) narrow branches, which face inward and form a circle around .5 mm. wide hollow center. At about 1 mm. above the base of the disk five or six branches on one side of the circle bend sharply outward and begin to bifurcate rapidly so as to make a fan-shaped expanse about 18 mm. long and 15 mm. wide. This expanse is gently curved outwards and downwards, like a spoon or a scoop. This "spoon" has a very short "handle," the circular bunch of the initial branches. Zooecia are arranged in two to five rows; the largest number of four or five rows continues for a distance of one or two fenestrules below bifurcations, but occasionally also occurs for a short distance along ordinary branch, and then changes distally to three rows, which is perhaps the most common number of rows. The branches have always only two rows of zooecia just above bifurcations, the third row is added at a distance from ½ to 3 fenestrules from the point of bifurcation. When in two rows, the zooecial chambers have sub-pentagonal outline at their bases. Lower hemisepta are occasionally developed in these, and, less frequently, in other zooecia. Apertures have low and narrow peristomes, and are spaced the width of their own diameter apart. The surface between them is smooth. Nodes occur between them somewhat irregularly, but usually in the middle of a branch. Less frequent than nodes are circular depressions of uniform size, about 1½ the diameter of the apertures, and always directly under the latter.

Fenestrules are subquadrate; the dissepiments average the width of fenestrules, smooth and depressed on obverse, flush with the branches on reverse. Branches usually smooth on reverse, but in the distal part of the zoarium they are grooved on the reverse, the grooves becoming deeper toward the periphery.

Meshwork formula is 12–16/8–8.5 (to 10 near the base)//18–20/13–20. There are usually 4½ apertures per fenestrule. Nodes tend to be lined along the middle of the branches, but no striae or carinae are developed on obverse.

Discussion.—Polypora ovicellata is undoubtedly closely related to *Polypora biseriata* Ulrich from the Warsaw, and to *Polypora insculpta* Ulrich (*P. whitei* var. *insculpta* of authors) from the "Lower Coal Measures" at Seville, Illinois. In its meshwork it is intermediate between these two species, but nearest to *P. insculpta* (Table 5). The Redoak Hollow species is more nearly like *P. insculpta* in regard to size and spacing of apertures and nodes, and smooth surface of the obverse. The obverse in *P. biseriata* is coarsely costate, and the apertures are comparatively smaller and spaced more than their diameter apart. It is also known to develop occasional circular de-

TABLE 5.—PRINCIPAL MEASUREMENTS OF *Polypora biseriata* GROUP

	Branch per 10 mm.	Fenestr. per 10 mm.	Apertures per 5 mm.	Nodes per 5 mm.	Age
P. insculpta Ulrich	9–10	9	19	irregular	L. Pennsylvanian
P. ovicellata, n. sp.	12–16	8–8.5	18–20	13–20	Readoak Hollow
P. biseriata Ulrich	17–19	14	17–18	11	Warsaw

pressions (ovicells?) just below the apertures, but these are of the same size as the apertures. The dissepiments in *P. insculpta* are very thin, less than ½ the width of the branches. Obverse in the latter is also much like that in *P. ovicellata*; generally smooth, but with locally developed longitudinal grooves. The surface of the obverse usually sags along the middle of the widest portions of the branches, usually for a distance from two to three fenestrules below the points of bifurcation. Similar, but less pronounced sag is developed at a few points along the wider branches in *P. ovicellata*.

POLYPORA DEBILIS Elias, n. sp.
Pl. 45, fig. 4–7; Pl. 48, fig. 4

This new *Polypora* is usually very fragmentary because of the apparent fragility of the zoarium: it is made of about .6 mm. wide branches, which are connected by very slender (.15–.2 mm. across), long (1 mm.), and widely spaced dissepiments.

Branches are elliptical in cross-section. Along their convex obverse are five to six rows of round apertures. Their peristomes are only slightly raised above the smooth inter-zooecial surfaces, and the occasionally developed thin wavy carinae tend to separate the longitudinal rows of the apertures. There are also very few small and low nodes scattered between the apertures. The reverse of the branches is convex, their sides are finely but distinctly grooved, and so are the dissepiments on obverse and reverse.

Meshwork formula is 7/4.5//16.

Discussion.—The slenderness of the dissepiments in contrast with the sturdiness of the branches is the most characteristic feature of the new species, which distinguishes it from the many species of *Polypora* described from the upper Morrow by Mather (1915). All his species have much wider dissepiments which combine with wide branches in making small fenestrules and durable zoaria.

A Chester form, *Polypora cestriensis* Ulrich (1890, p. 594–595, pl. 55, fig. 4–4c; pl. 60, fig. 7–7c) has practically the same meshwork formula as *P. debilis:* 8/5–6//17, and differs from the new species only in flatter branches, wider dissepiments, and fewer rows of zooecia, normally three to four.

THAMNISCUS ERECTUS Elias, n. sp.
Pl. 46, fig. 4–6

Beautifully preserved example of an apparently nearly complete small zoarium of *Thamniscus*, and another less well preserved zoarium have been recovered from the Redoak Hollow, in form of external mold of both obverse and reverse. Most interesting and peculiar is the completely preserved elongated basal part of the zoarium; a slender cylindrical stem 6 mm. long. It is this mode of growth together with the spacing of zooecial apertures and of bifurcations that differentiate *T. erectus* from the few other known Carboniferous species, all of which are rare.

The holotype is attached to the reverse of *Polypora debilis*(?) (Pl. 48, fig. 4) with the spacing of the fenestrules, 15 per 10 mm., and of the apertures, 15 per 5 mm., as measured on the small fragment serving the substratum. The attachment is accomplished by an abrupt spreading of the stem just above the surface of attachment; the spreading part is about three times as wide as the diameter of the stem, and tends to be divided into a few root-like lobes. The stem and its basal lobes are longitudinally striated, but somewhere higher along the stem, between 1 and 3 mm. above the base, apertures appear on one side, which thus becomes obverse of the zoarium. At 6 mm. above the base, the stem bifurcates symmetrically at an acute angle of 40–45°, and

one of the two branches bifurcates again about 1.5 mm. higher, while the other continues without bifurcation for a distance of about 3 mm., the most distal point of the preserved part of the zoarium.

The diameter of the stem at the base is .55 mm. and attains .65 mm., 3.5 mm. above the base, which is also its diameter just below the bifurcation. The diameter of the bifurcating branch is .55 mm., and that of either of the branches above the second bifurcation is .44 mm. The diameter on the non-bifurcating branch remains about .50 mm. all along its length.

The apertures on the obverse are closely spaced in four to five rows, in checkerboard fashion. Apertures are oval with very low or suppressed peristome, slightly more than their long diameter apart along the longitudinal rows, spaced about three apertures per 1 mm. along a row. Narrow undulating grooves separate one longitudinal row of apertures from another.

The reverse is uniformly striated all along the zoarium, the striae averaging 5 per .2 mm. on the stem, but become gradually denser in the distal half of the non-bifurcating branch, up to 10 per .2 mm. at its distal end, which, perhaps, indicates termination of growth.

Discussion.—The mode of initial growth in form of a single zoarial branch (stem) is not normal for Fenestellidae, and *Polypora* in particular, from which genus *Thamniscus* is presumably derived. Particularly, the initial development of the latest Pennsylvanian and of early Permian species of *Thamniscus*, as I have repeatedly observed on many individuals, proceeds in form of several concentric rows of zooecia, which make a circular cushion; the subsequently developed zooecia are segregated in several (usually six to eight) radiating branches, which begin to rise gradually above the level of the cushion. The growth of most of these branches becomes arrested soon after they rise, as the remaining few continue to rise, but only one (seldom two) of them attains a full zoarial development predominating over all the others which remain short and unbifurcated. Contrary to this, the just described early stages of development seem largely omitted in *T. erectus*; but, because only external mold of the zoarium is preserved and all zooecial chambers destroyed, it is conceivable, and even probable, that the earliest or "cushion" stage of zoarial growth is present, though covered by the expanded base of the stem. There is no room within it to cover the next stage, the one with short radiating branches, so that evidently only one branch has formed. Apparently it quickly attained an upright position and became the single zoarial stem. This stem did not start to bifurcate until it rose to 6 mm. above the base, while in nearly all the zoaria of *Polypora* and *Thamniscus* the bifurcation starts within one or two millimeters above the base, and proceeds repeatedly and frequently from there on.

Among the previously known slender and moderate to scarcely bifurcating species of *Thamniscus*, *T. sculptilis* Ulrich from the Keokuk of Kentucky, and *T. furcillatus* Ulrich from the Chester of Illinois are similar to *T. erectus*. Both species have three to four (to five just before bifurcation) rows of apertures, as in *T. erectus* but only in *T. furcillatus* are they as regularly alternating in the adjoining rows as in the new species from the Redoak Hollow. Further similarity of *T. furcillatus* to *T. erectus* is the width of the branches, from .5 to .7 in the former; the presence of slightly undulating low ridges between the longitudinal rows of apertures; the spacing of the apertures, "about seventeen in 5 mm." in the former; and the angle of bifurcation, "between 60° and 90°" in the former. However, *T. erectus* differs from *T. furcillatus* in having much shorter interval between the bifurcations, which are "rarely less than 7 mm. apart" in the latter. Also, the apertures in *T. erectus* are distinctly elliptical, while in *T. furcillatus* they are circular.

The described differences seem sufficient to consider the form from the Redoak Hollow a new species, though its close relationship to *F. furcillatus* is apparent, and it is probably its direct descendent. Another descendent could be *Thamniscus tenuiramus* Rogers (1900, p. 9, pl. 12, fig. 5,5a) from the Missouri series and higher Pennsylvanian beds of Kansas.

SEPTOPORA cf. S. PINNATA Ulrich
Pl. 48, fig. 12

Septopora pinnata ULRICH, 1890, Ill. Geol. Surv., vol. 8, p. 633; pl. 64, fig. 7; pl. 65, fig. 1,1a. CONDRA, 1900, Nebr. Geol. Surv., vol. 2, pt. 1, p. 96–97, 114; pl. 20, fig. 1,2.

The species was originally very briefly described, but well illustrated by Ulrich. Rogers differentiated from it his *S. interporata* on the evidence of the lateral branches being "straighter and more regular," and also because of more frequent occurrence in it of the "accessory pores." However, Condra places *S. interporata* in the synonymy of *S. pinnata* "without much doubt"; indeed, frequency of occurrence of the accessory pores (smaller openings on the reverse and obverse surfaces, frequently developed between the apertures) is variable in this and other species of *Septopora* and *Acanthocladia*, while greater regularity and straighter shape of the branches might have been due to environmental rather than genetic control. At any rate, in as far as the identification of the small fragment from the Redoak Hollow is concerned, it seems generally related to *Septopora pinnata* in its broader sense as understood by Condra. The single fragment consists of rigid axis .5 mm. wide from which straight lateral branches depart at an angle of about 50°. These branches are only half as wide as the central axis, a feature more nearly like that in the original example of *S. pinnata* described by Ulrich, than in those described by Rogers and by Condra. The rigidity of the axis and the lateral branches are more nearly like those in Rogers' species. However, the example from the Redoak Hollow differs from that described by Rogers by having only very few accessory pores, which are about as scarce as in the original *S. pinnata* Ulrich. The apertures in the axis of the example from the Redoak Hollow are small, circular, two to three times the width of their own diameter apart.

A feature of special interest in the Redoak Hollow form is the elongated pentagonal outline of the zooecial chambers in its lateral branches. The branch in which these chambers are preserved sends off at sub-perpendicular angles two "fertile dissepiments" or branchlets of second order, in which the outline of the chamber is quite different, having the form of shortened triangles to trapezoids. Outline of the zooecial chamber in *S. pinnata* has not been previously described.

Discussion.—The example from the Redoak Hollow constitutes the earliest known record of *Septopora pinnata*, all previously described examples coming from the post-Morrow Pennsylvanian beds. It seems that the slender, *Penniretepora*-like *Septopora decipiens* Ulrich (1890, p. 630–631, pl. 66, fig. 9) from the Chester of Kentucky is the ancestral stock of *S. pinnata*. The smallness of its apertures and their distant spacing, as shown on Ulrich's sketch (but not as described by him) is nearer to the size and spacing of the apertures in *S.* cf. *S. pinnata* from the Redoak Hollow than to that in the Pennsylvanian examples of *S. pinnata*.

PENNIRETEPORA ARDMORENSIS Elias, n. sp.
Pl. 48, fig. 13–16

Several fragments of *Penniretepora* are characterized by features that set them apart from all previously known species of the genus. Spacing of the apertures on the main axis (called "midrib" by authors) is such that every other aperture is placed at the departure of regularly disposed lateral branches, and the intermediate apertures are placed in the middle of the space between these branches. There is no carina on the obverse, but the two rows of apertures are separated by a set of three parallel, serrate "lines" or "striae," the middle line slightly stronger than the other two (pl. 48, fig. 13). The band made of these striae meanders gently and regularly between the two rows of the apertures, which are disposed in alternate manner. The branchlets on the opposite sides of the axis tend to be sub-opposite, and not alternate, but they cannot be exactly opposite because they also tend to be disposed at every other aperture. Apertures have irregular but much elevated peristomes. The reverse is only occasionally and faintly "striated." In one fragment stronger striae border the apertures laterally and also along the medial line of the obverse, where the striae are more prominent, though generally irregular and not forming a three-row band. Poorly developed sculpture and narrower apertures suggest dying out of the zooecia in the earliest part of the zoarium, a feature generally characteristic of bryozoa. In the basal part of the zoarium, the lateral branchlets are spaced a little less regularly than in the mature part, tending to be more distantly spaced, while the apertures are spaced in the same way as in the distal part, 14 to 15 per 1 mm.

Basal part of the axis is only slightly wider than the distal part, and is attached at a

right angle to seemingly much worn out branch of a fenestellid bryozoan.

The molds of the zooecial chambers are preserved, demonstrating their triangular to trapezoidal outline at the base, and their strong chimney-like vestibula extending upward with a slight antero-lateral inclination (pl. 48, fig. 16). Shorter and more trapezoid are the zooecial chambers in the lateral branchlets; no more than four zooecia in each branchlet, their apertures apparently in two alternate rows.

Discussion.—The species belongs to the group in which the zoaria are ornamented along the center by three (or less) low and narrow elevations, usually called "striae," instead of having elevated carina along the median line. This group is typified by its most common species *Pennirетepora trilineata* (Meek). *P. ardmorensis* differs from the latter by lateral undulations of the band of three striae, which are quite straight in *P. trilineata*. Besides, the lateral branchlets of the latter are much stronger and spaced about 1½ times wider, so that upon the main axis three apertures are disposed between their bases.

Three species of *Pennirетepora* previously described have the apertures spaced regularly in twos per the interval between the lateral branches, as in *P. ardmorensis*. One is *P. minor* Ulrich from the Waverly series of Ohio, which differs from *P. ardmorensis* by a larger number of branches and zooecia per given space, and by having distinct carina ornamented with nodes (Ulrich, 1888, p. 77, pl. 14, fig. 7,7a). The other is *P. youngi* Ulrich (1890, p. 615–616, pl. 66, fig. 3) from the Keokuk group of Kentucky and Iowa. This species also has a strong nodate carina, and its apertures are spaced wider apart than in *P. ardmorensis*. The third is *P. bellula* Ulrich from the "base of the Coal Measures" at Seville, Illinois; this species is more nearly like *P. ardmorensis* than *P. minor* or *P. youngi*. It has no definite carina, the obverse of its axis being "marked with flexuous striae, strongest near the center of the midribs, where also a row of small and widely separated (.8 mm.) nodes may be observed" (Ulrich, 1890, p. 619, pl. 66, fig. 8–8b). This lower Pennsylvanian form has less regular arrangement of the striae that take the place of medial carina, and it has a row of nodes along the center—features unlike those in *P. ardmorensis*. The spacing of the apertures upon the axis, and also upon the lateral branches, is 1½ as wide as the spacing of the corresponding elements in *P. ardmorensis*.

It seems that neither *P. minor* nor *P. youngi* are ancestors of *P. ardmorensis*, but such could be *Pennirетepora flexuosa* Ulrich (1890, p. 615, pl. 66, fig. 4–4c) from the Keokuk group of Kentucky. This species has no carina, and instead, its obverse "is marked with strong flexuose striae, those along the center of the branches a little the strongest." Ulrich's sketch illustrates this sculpture well, shows no regularity in the development of the "striae" into a three-fold central band, but in it the lateral "striae" come in and out of the central part irregularly. The spacing of the apertures in relation to the lateral branches in this form is also different from that in *P. ardmorensis*, as there are in average three apertures on each side of the axis in the intervals between the lateral branches. While *P. flexuosa* probably gave rise to *P. ardmorensis*, the latter probably gave rise to *P. bellula* and *P. trilineata* in post-Redoak Hollow time.

In the collection from the Otterville at Ardmore, in the Nebraska Geological Survey, the species *P. trilineata* has the following numerical characteristics: width of main axis .35 mm.; number of lateral branchlets 12 per 10 mm.; and number of apertures 17–18 per 5 mm. About 3 apertures are spaced between each pair of the lateral branchlets. In this form the three central "striae" are equally weak, while in the typical *P. trilineata* from the higher Pennsylvanian the median is stronger than the two lateral "striae." This seems to indicate that *P. ardmorensis* is a direct ancestor of *P. trilineata*, the variety of the latter in the Otterville being an intermediate form.

BRYOZOANS AS AGE INDICATORS

The bryozoans are more like the corresponding Chester forms than any other major phyletic group of the Redoak Hollow fauna. Conspicuous in the Redoak Hollow bryozoan faunule is the large number of species of *Fenestella*, the presence of many species of *Archimedes*, and the scarcity of the species of *Polypora*. In contrast with this the

bryozoans in the Morrow consist of many species of *Polypora*, while the number of species and specimens of *Fenestella* is small, and *Archimedes* is absent.

There are many long-ranging species of *Fenestella* in the Redoak Hollow which are known to extend from the upper Mississippian through nearly all the Pennsylvanian. However, such long ranging species did not remain entirely unchanged during their range through time, and some small but measurable changes occurred in them, particularly in the spacing of their principal elements, the dissepiments and zooecia. Their representatives in the Redoak Hollow are nearer to those in the Mississippian than those in the lower Pennsylvanian rocks.

Species of *Archimedes* are particularly useful for exact correlations. In table 5 are entered new data on stratigraphic distribution of the species of *Archimedes* collected and identified by me in the Chester, and particularly Upper Chester of Illinois, in combination with the previously published data on *Archimedes* for Illinois and Kentucky by Ulrich (1890, 1905, 1917), Butts (1917), McFarlan (1942), and Condra & Elias (1944). Against these data are plotted (1) list of species in the Pitkin of Arkansas and Oklahoma as per identifications by Easton (1942, 1943) and myself, and (2) list of Redoak Hollow forms.

When counting only identical forms, this table shows that out of four species that make their last appearance in the Glen Dean formation one is known in the Pitkin, but none in the Redoak Hollow; out of two making last appearance in the Menard one is known in the Pitkin, but none in the Redoak Hollow; out of five making last appearance in the Clore three are known in the Pitkin, and one in the Redoak Hollow; and out of six making last appearance in the Kinkaid three are known in the Pitkin and

TABLE 6.—LIST OF THE BRYOZOA FROM THE REDOAK HOLLOW WITH AN INDICATED RELATIONSHIP TO THE KNOWN EARLIER AND LATTER FORMS

Pre-Redoak Hollow	Redoak Hollow	Post-Redoak Hollow
Marcusodictyon priscum (Bassler)	*Marcusodictyon priscum* var. *vinei*, n. var.	
Vinella? multiradiata Ulrich & Bassler	*Vinella bilineata*, n. sp.	
Eridopora macrostoma Ulrich	*Eridopora* (*Discotrypella*) *radiata*, n. subg., n. sp.	
Cheilotrypa regularis Easton	*Cheilotrypa distans*. n. sp.	
	Pycnopora ovatipora, n. sp.	
Stenocladia frondosa Girty	*Stenocladia? basslers*, n. sp. (n. gen.?)	
	Strebloplax crustacea, n. gen., n. sp.	
	Tabulipora simplex, n. sp.	
Tabulipora tuberculata Prout	*Tabulipora* cf. *T. tuberculata* Prout	
Tabulipora microfistulata Easton	*Tabulipora macnairi*, n. sp.	*T. ohioensis* Foerste
Rhabdomeson gracile (Phillips)	*Rhabdomeson* (*Rhombopora*) *rogersi*, n. sp.	
	Rhabdomeson (*Rhombopora*) *foerstei*, n. sp.	
	Rhabdomeson? (*Rhombopora*) *ulrichi*, n. sp.	
Streblotrypa nicklesi Ulrich	*Streblotrypa nicklesi* Ulrich	*S. prisca* Gabb
Fenestella exigua	*Fenestella exigua* var. *springerensis*, n. var.	*F. tetratheca* Condra & Elias
	Fenestella morrowensis Mather	*F. morrowensis* Mather
	Fenestella ovatipora, n. sp.	
Fenestella frutex M'Coy	*Fenestella* cf. *F. frutex* M'Coy	
Fenestella chesterensis Condra & Elias	*Fenestella* cf. *chesterensis* Condra & Elias	*F. stocktonensis* Condra & Elias
Fenestella serratula Ulrich	*Fenestella serratula* Ulrich	*F. serratula* Ulrich
Fenestella cumingsi Condra & Elias	*Fenestella cumingsi* Condras & Elias	*F. cumingsi* Condra & Elias
Fenestella tenax Ulrich	*Fenestella tenax* Ulrich	*F. tenax* Ulrich
	Fenestella rara, n. sp.	*F. perminuta* Ulrich
Fenestella cestriensis Ulrich	*Fenestella cestriensis* Ulrich	
Fenestella paradisensis Condra & Elias	*Fenestella paradisensis* Condra & Elias	
	Fenestella paradisensis var. *ardmorensis*, n. var.	
	Fenesteverta nicklesi, n. gen., n. sp.	
Archimedes swallovanus Hall	*Archimides pseudoswallovanus* n. sp.	
Archimedes stoyanowi Condra & Elias	*Archimedes ardmorensis*, n. sp.	
Archimedes meekanus Hall	*Archimedes* cf. *A. meekanus* Hall	
Archimedes meekanoides McFarlan	*Archimedes meekanoides* McFarlan	
Archimedes perminimus Ulrich	*Archimedes* aff. *A. perminimus* Ulrich	
Archimedes pitkinensis n. sp.	*Archimedes pitkinensis* n. sp.	
Archimedes distans Ulrich	*Archimedes distans* Ulrich	
Archimedes rigidus, n. sp.	*Archimedes rigidus* n. sp.	
Archimedes sublaxus Ulrich	*Archimedes* cf. *A. sublaxus?* Ulrich	
Polypora biseriata Ulrich	*Polypora* (*Polyporella*) *ovicellata*, n. sp.	*P. whitei* Ulrich
Polypora cestriensis Ulrich	*Polypora debilis*, n. sp.	
Thamniscus fasciculatus Ulrich	*Thamniscus erectus*, n. sp.	*T. tenuiramus* Rogers
Septopora decipiens Ulrich	*Septopora* cf. *S. pinnata* Ulrich	*Septopora pinnata* Ulrich
Penniretepora minor Ulrich	*Penniretepora ardmorensis*, n. sp.	*P. bellula* Ulrich

Note: Solid lines indicate close relationship of the species; dotted lines indicate more distant relationships.

TABLE 7.—STRATIGRAPHIC DISTRIBUTION OF *Archimedes* IN THE CHESTER OF AMERICA

Species	Renault	Paint Creek	Golconda	Glen Dean	Menard	Clore	Kinkaid	Pitkin	Red-oak Hollow
1. *A. pseudoswallovanus*, n. sp.									+
2. *A. ardmorensis*, n. sp.							+		+
3. *A. pitkinensis*, n. sp.								+	+
4. *A. terebriformis* Ulrich		+	+	+			+	+	
5. *A. distans* Ulrich		+	+	+	+	+	+		+
6. *A. meekanus* Hall		+	+	+	+	+	+		+
7. *A. meekanoides* McFarlan	+	+			+		+		+
8. *A. invaginatus* Ulrich	+	+	+	+	+	+	+	+	
9. *A. rigidus*, n. sp.						+			+
10. *A. perminimus* Ulrich					+				aff.
11. *A. swallovanus* Hall			+	+	+			+	
12. *A. symmetricus* McFarlan		+	+	+	+	+			
13. *A. intermedius* Ulrich		+	+	+	+	+		+	
14. *A. bassleri* McFarlan		+	+	+	+	+			
15. *A. communis* Ulrich		+	+	+	+	+		+	
16. *A. conicus* McFarlan		+	+	+	+				
17. *A. compactus* Ulrich		+	+	+					
18. *A. proutanus* Ulrich		+	+	+				+	
19. *A. laxus* Hall		+	+	+					
20. *A. sublaxus* Ulrich		+	+	+			cf.		cf.
21. *A. confertus* Ulrich	+	+							
22. *A. tortuosus* McFarlan	+								
23. *A. fosteri* C. & E.								+	
24. *A. compactoides* C. & E.								+	
25. *A. moorei* C. & E.								+	
26. *A. fragilis* C. & E.								+	
27. *A. lunatus* C. & E.								+	
28. *A. magnus* C. & E.								+	

four in the Redoak Hollow. Counting the common forms in a somewhat different way we can see that the Pitkin and Glen Dean-Menard interval have two species in common; Pitkin and Clore four, and Pitkin and Kinkaid three. On the other hand the Menard and the Redoak Hollow have possibly only one species in common, *A. perminimus;* Clore and Redoak Hollow three; and Kinkaid and Redoak Hollow four. Hence the occurrence of species of *Archimedes* tends to indicate equivalency of the Upper Pitkin to the Clore, and of the Redoak Hollow to the Kinkaid of the classical Mississippian. Besides, the occurrence of *A. pseudoswallovanus* exclusively in the Redoak Hollow may indicate its taking place of *A. swallovanus*, a very common form in the Menard and the Pitkin, but unknown in the Clore and the Kinkaid; and the Clore has another *swallovanus*-like species, its exclusive, presently undescribed form.

Cheilotrypa distans also tends to indicate a younger age for the Redoak Hollow than for the Pitkin, as it appears to be more advanced.

BIBLIOGRAPHY for all portions is to appear in Part 4 of this study.

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BIOSTRATIGRAPHY AND INTER-REGIONAL CORRELATION OF THE UPPER SENONIAN AND LOWER PALEOCENE OF EGYPT

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ABSTRACT—The biostratigraphic characters of the Campanian, Maestrichtian, Danian and Montian of Egypt are defined, and a world wide survey of these characters is made. Long range correlation of the Egyptian microfauna helps in establishing universal stratigraphy of these geologic episodes.

INTRODUCTION

THE aim of the present work is to define the biostratigraphic characters of the upper Senonian (Campanian and Maestrichtian) and the lower Paleocene (Danian and Montian) of Egypt, to establish the boundaries between these ages in Egypt, and to show their wide range of correlation with their contemporaries in many parts of the world. This study links the Egyptian formations with the history of the realm of the Tethys geosyncline, which has previously been shown to be very similar in episodes, and with almost identical faunas in many of its widespread parts. Examples are found in the Caucasus, Southern Europe, the Middle East and North Africa, as well as in the Gulf Coastal Region of the United States and the adjacent areas of Mexico and Trinidad.

The data on which the present investigation is based are the results of the study of 4 sections in Western Sinai, 1 in Farafra, 2 in the Eastern Desert, 1 in the Nile Valley and 2 in the Western Desert. All but the Farafra section (LeRoy, 1953), have been thoroughly examined by the writer. The uppermost Cretaceous and the earliest Tertiary ages of Egypt are represented throughout the country by widespread uniform deposits. The individual formations have been considered, and are still regarded by some recent workers, as time units. This interpretation has been the subject of considerable discussion over the past 50 years, and the present investigation seeks to elucidate the problem. It has already been demonstrated that the upper formations are only rock units (Nakkady, 1951), and this concept is herein expanded to demonstrate that all of the formations are independent of time boundaries.

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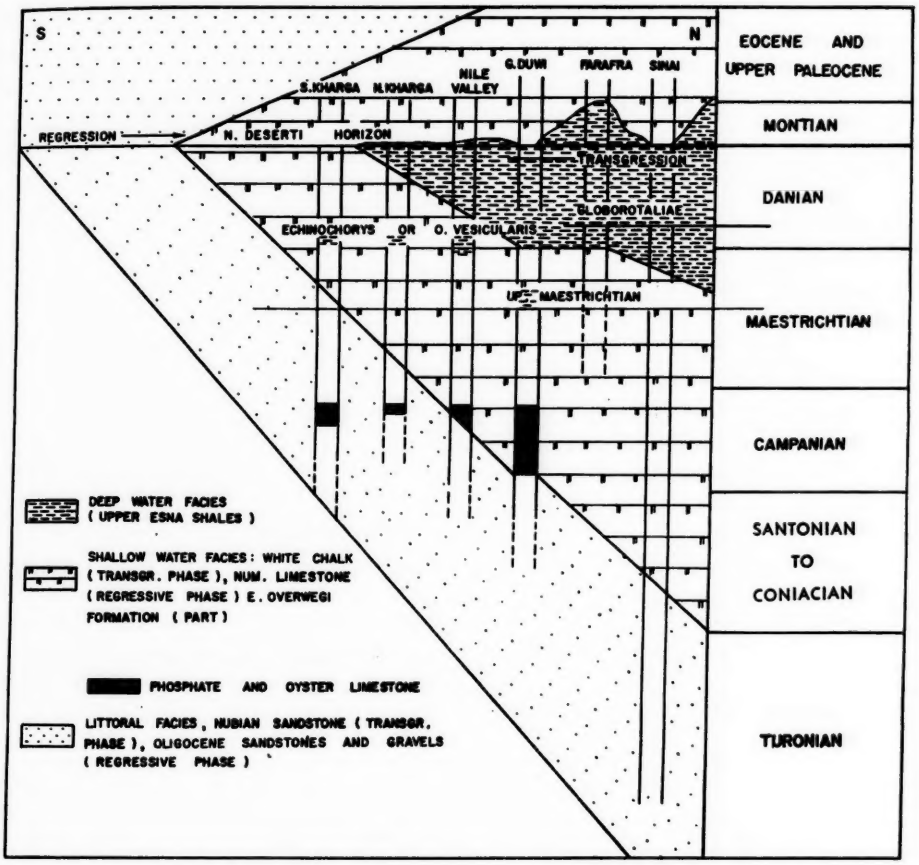
THE STRATIGRAPHIC SEQUENCE

1. Typically the sequence starts at the base with the "Nubian sandstone and phosphate formation," a series of multicolored sandstones, shales or clays, phosphate, chert and oyster limestones. The characteristically nonfossiliferous sandstones are of variable thickness and lithologic character; they are overlain by the phosphate together with the accompanying chert and oyster limestone.

2. The Nubian sandstones are conformably overlain by the *Exogyra overwegi* formation," a succession of clays, marls and limestones, with *Exogyra overwegi* as the characteristic fossil. The associated fauna includes *Isocardia chargensis, Scaphites kambysis, Roudairia drui, Libycoceras khargense, Cardita libyca* and *Cardita beaumonti.*

3. Conformably lying over the *Exogyra overwegi* formation are the "Lower Esna



TEXT-FIG. *1*—Schematic chart showing gradual shifting of facies due to transgressions and regressions.

shales." These ash-gray paper shales contain the following fossils, occasionally beautifully preserved in hard limonite: "*Nautilus*" *desertorum*, "*N.*" *applanatus*, "*N.*" *danicus*, *Nucula chargensis*, *Alaria schweinfurthi*, *Leda leia*, *Natica farafrensis*, *Pecten farafrensis*, *Schizorhabdus libycus*, *Ventriculites poculum*, and *Diospyros schweinfurthi*.

4. The White Chalk: the white chalk, with *Echinochorys fakhryi* [=*Ananchytes ovata*] in the typical area, contrasts strongly with the conformable overlying and underlying gray shales, clays and marls of the Upper and Lower Esna shales. This formation is well represented in the Southern Oases of the Western Desert. It is also known from the Nile Valley, Eastern Desert and Sinai where it has different ages in various districts. The White Chalk offers an example of time boundaries cutting through rock units. In the Kharga Oasis (Gabal Ter and Gabal Um el Ghanayem) its microfauna is definitely of Danian character, whereas it is all Cretaceous (Maestrichtian or Campo-Maestrichtian) in the Eastern Desert and Sinai.

5. "The Upper Esna shales": these richly foraminiferal laminated gray clays, shales and marls, are devoid of macrofossils or very scarcely fossiliferous. This unit provides evidence for the rock unit character of the individual formations. The Cretaceous-Tertiary time boundary cuts through these shales at various intervals in different parts of the country, nullifying a previously assumed position as a rock-time unit.

6. The "Operculina limestone formation": In areas where sedimentation has been

continuous, the upper layers of the Esna shales are of Danian and/or Montian age and become largely marls. These marls pass in many cases imperceptibly into the overlying younger Paleocene formation, the *Operculina* limestone and chalky marl. The leading fossils in this formation, *Nummulites deserti, N. globulus, Operculina libyca* and *Lucina thebaica*, are associated with *Cardium gigas, Cardium picteti, Cyprina scutellaria* and *Conoclypeus delanouei.*

The typical sequence of formations described as found in Gabal Um el Ghanayem (Kharga Oasis) is not maintained in every locality. Usually one or more of the formations displays much variation in thickness and faunal character, even in nearby areas with an otherwise typical sequence.

Pronounced lateral variation is noted in the formations of different localities; therefore it is better to refrain from generalized thickness designations. In a comparatively small locality like Kharga Oasis, the lower Esna shales vary from 12 to 38 m. in thickness, the *Echinochorys* chalk from 6 to 20 m. and the Upper Esna shales may reach 80 m. or be completely absent.

Tracing these marked variations in selected representative Egyptian areas would explain the comparative stratigraphy of the country in the time interval Upper Senonian-Lower Paleocene. However, such a study would demand a lengthy discussion beyond the scope of this work. The schematic chart shows gradual and continuous shifting of facies from north to south due to transgressions and regressions. The equivalency between the formations in the various localities is drawn on similarity in lithology and stratigraphic position and not on synchronism.

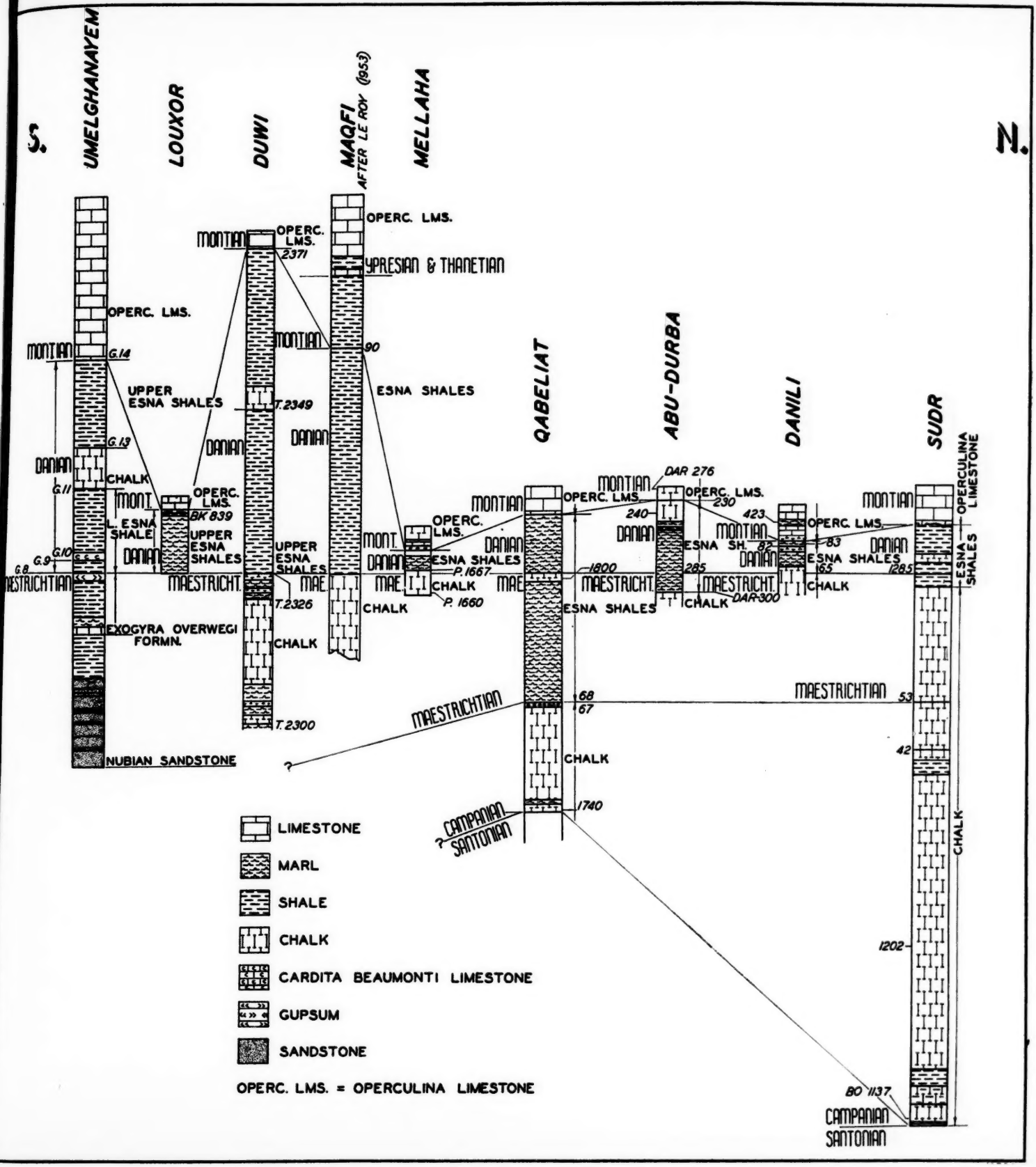
From this schematic chart it is apparent that the transgression came from the north where earlier Upper Cretaceous had already been deposited in northern Sinai. In Sinai, beginning with early Campanian time, shallow water marls and chalks (massive chalk and bedded chalk of Raha scarp and G. Qabeliat) were deposited. Whereas much shallower deposits (the phosphates, the closely associated oyster beds and the *Exogyra overwegi* formation) or littoral facies (Nubian sandstones) were being accumulated in the south. The presence of some deep water intercalations (lower Esna shales and the shaly bands in the *Exogyra overwegi* formation) are due to rhythmic marine oscillations. Still later, deeper waters prevailed over almost all Egypt and led to the formation of the upper Esna shales. All Egyptian seas were shallow again at the close of the early Paleocene time. This general recession may have accounted for the explosive evolution of *Nummulites* and formation of the *Operculina* and Nummulitic limestone. In areas where the Upper Esna shales and/or the overlying *Operculina* limestone seem to be missing, shallowing of the seas must have started earlier and resulted in the complete emergence of the sea floor in these localities until they were resubmerged under later Tertiary waters. This condition then accounts for the hiatus often observed between different members of the Upper Cretaceous and the unconformably overlying middle or upper Eocene.

The facies chart gives an explanation for many of Egypt's stratigraphic problems:

1. That formations are not time units is demonstrated. The deep water facies (upper Esna shale) is of upper Maestrichtian, Danian and Montian ages in the north, but of Montian age only in the extreme south and of intermediate ages in the central areas. The same relationship has been observed in the White Chalk and some other underlying formations belonging to the shallow water and littoral facies.
2. It accounts for the occurrence of a Montian fauna in the uppermost layers of the upper Esna shales in the north and central districts, and its presence only in the overlying *Operculina* limestone formation of the regressive phase in the south.
3. It explains why *Nummulites deserti* seems to appear earlier in the section in the north and central parts, *e.g.* El Guss Abu Said and Maqfi sections, but is retarded (appearing just below the *Operculina* limestone) in the Esna shales of the more southern districts (Gabal Um el Ghanayem, Kharga).

BIOSTRATIGRAPHIC CHARACTER OF THE UPPER SENONIAN-LOWER PALEOCENE

A discussion and broad survey of the biostratigraphic character of the upper Senonian and lower Paleocene ages is possible because of the great wealth of literature on the Foraminifera of these ages in different countries. These faunas represent the climax of foraminiferal development and are of striking similarity or uniformity of


S.
N.
UMELGHANAYEM
LOUXOR
DUWI
MAQFI
AFTER LE ROY (1953)
MELLAHA
QABELIAT
ABU-DURBA
DANILI
SUDR
OPERC. LMS.
MONTIAN
YPRESIAN & THANETIAN
ESNA SHALES
UPPER ESNA SHALES
L. ESNA SHALE
DANIAN
CHALK
MAESTRICHTIAN
MAE.
MONT.
EXOGYRA OVERWEGI FORMN.
NUBIAN SANDSTONE
G.14
G.13
G.11
G.10
G.9
G.8
BK 839
T.2371
T.2349
T.2326
T.2300
P.1667
P.1660
90
1800
68
67
1740
53
42
1202
DAR 276
DAR 300
230
240
285
423
82
83
165
1285
BO 1137
CAMPANIAN
SANTONIAN
OPERCULINA LIMESTONE
LIMESTONE
MARL
SHALE
CHALK
CARDITA BEAUMONTI LIMESTONE
GUPSUM
SANDSTONE
OPERC. LMS. = OPERCULINA LIMESTONE

TEXT-FIG. 2

character in many regions. The classification utilized here for the stratigraphic interval, latest Mesozoic-earliest Cenozoic, *i.e.* Senonian and Paleocene, seems to be a logical one.

between it and the underlying Maestrichtian, "Tuffeau de Saint Symphorien," etc. This long-interrupted gap in deposition is partly or wholly represented in other areas by sediments which fill the lacuna between

Periods	Epochs		Ages
Tertiary	Paleocene	Upper	Sparnacian, Thanetian
		Lower	Montian, Danian
Cretaceous	Senonian	Upper	Maestrichtian, Campanian
		Lower	Santonian, Coniacian

MONTIAN

The type locality for this stage is in Mons (Belgium), where the "tuffeau de Ciply" has provided a fauna which to most authors represents the earliest Tertiary. The tuffeau de Ciply is separated from the underlying Upper Senonian "tuffeau de Saint Symphorien," with its *Belemnitella mucronata* fauna, by a wide lacuna; but is conformably overlain by the "calcaire de Mons" and the lower Landenian. The scanty fauna known from this area is almost identical with that of the so-called "calacire pisolithique" of the Paris Basin. There has been considerable divergence of opinion about the age of this *mammilated* Lithothamnium limestone; a question exists as to whether it is a true representative of the earliest Tertiary.

With a paleontologic insufficiency and a stratigraphical confusion concerning the name, it may seem advisable to choose another formation somewhere else in the world as a better representative for this early Paleocene episode and attach to it all the importance given to the Montian—were it not for the traditional value associated with the name. Besides, the name is apt to lose much of its stratigraphical prestige as the earliest Tertiary stage if the Danian, which is regarded as the true earliest Paleocene, will be stepped one stride upward in the scale. The choice of this formation in Mons to represent the earliest Tertiary is unfortunate because there is a strong break between the two stages and which contain examples of earliest Tertiary life.

The meager fauna of the type Montian, in its present reported shape, is rather difficult to correlate with that of other stratigraphically analogous formations in most parts of the world. It is true that Ten Dam (1947) and Marie claim a Montian age for the Bunde limestone of Limburg (determined as Middle Eocene by Van Bellen in 1946), on the grounds of identity of their faunas. But Ten Dam's and Marie's claims could also mean a wider range for the type Montian species, extending to the Lutetian of the Netherlands. Even if Van Bellen's fauna from the Bunde Limestone is accepted as representative of the type Montian fauna, it would be most insufficient as a type age indicator. The fauna having such wide-ranging species, extending in most cases to Middle Eocene, seems unworthy of being a type representative to a definite episode in the geological scale.

The fauna described by Ten Dam (1944) from the Paleocene of the northern Netherlands is quite different from that of southern Netherlands (Limburg). Apart from *Cibicides praecursorius* (Schwager), the other few common wide-ranging species are stratigraphically insignificant. The difference in character of the two faunas is thought to have been due to an isolation of the northern Netherlands during Montian time and the consequent similarity of the Limburg fauna

STRATIGRAPHIC POSITION OF THE DISCUSSED UPPER SENONIAN — LOWER PALEOCENE FORMATIONS.

AGES / REGIONS		EGYPT	NORTH EUROPEAN BASINS			TETHYS BASINS			ATLANTIC AMERICAN BASINS			CALIFORNIA
			FRENCH - BELGIAN	NETHERLANDS	SCANDINAVIAN	CAUCASEAN - CRIMEAN	MIDDLE EAST	ALGERIA	U.S. GULF - COAST REGION	EASTERN MEXICO	TRINIDAD	
LOWER PALEOCENE	MONTIAN (S.L.)	Nummulitic Limestone (part) Upper Esna Shales (part)	Tuffeau de Ciply, Calcaire pisolithique	Limburg's Bunde limestone (part)	Green sand of Lellinge Cranie Limestone (part)	Kod Spring	Paleocene of Israel (part) – Upper part of Imperatorum Section (Iraq)	Etage A of Sigal	Upper Midway Wills Point Nahoole	Chicontepec	Soldado, Lizard Springs (part)	E. Zone of Laiming
	DANIAN	Upper Esna Shales (part) Echinocharys Chalk (part) Lower Esna Shales (part)			Cranie Limestone (part) & Bryozoan Chalk of Denmark lime sands of Sweden	Tsilca	Reiss' Danian and Paleocene (part) of Israel		Lower Midway Kincaid	Velasco	Lizard Springs (part)	
UPPER SENONIAN	MAESTRICHTIAN	Upper Esna Shales (part) Echinocorys vulgaris Chalk (part) Lower Esna Shales (part) E. overwegi beds, Nubian Sandstone (part)	Craie de Meudon (part) Craie de Ciply	Maestricht buffaceous Chalk Kunrade Chalk	Mucronalen Senon Chalk	Kalkh	Reiss' Maestrichtian Campanian and Senonian of Israel	Etage B of Sigal	Navarro	Mendez	Chaudiere and Terouba	Zones A2 - D1 of Goudkoff
	CAMPANIAN	O. Vesicularis Chalk (part) Phosphate and Apatite limestone Nubian Sandstone (part)	Craie de Meudon (part) Craie superieure de Reims, Craie Sup. d'Harbillers, Craie phosph. de la Picardie	Gulpen Chalk, Herven Green sands, Aken quartz Sands	Mucronalen Senon Chalk (part) Quadratalen Senon Chalk Marl and Sandstone			Etage C of Sigal	Taylor	Papagallos		Zones D2 - F2 of Goudkoff

TEXT-FIG. 3

only to that of the French-Belgian Basin. However, Brotzen (1948) stated that many typical species are common between the northern Netherlands and Swedish Paleocene and that the former is very similar to the higher Paleocene of Denmark.

The Paleocene of Scandinavia has been studied exhaustively by Brotzen (1948), whose work indicates that:

1. There is a break between the Danian and the rest of the overlying Paleocene both in Denmark and Sweden, with basal conglomerates at the top of the Danian, containing remains and fossils from the Danian.
2. The Paleocene of Sweden is equivalent to the lowest part of the Danish Paleocene known from the Copenhagen region, the macro- and microfauna being very much the same in the two regions.
3. The fauna of the Paleocene of Sweden and the Lower Paleocene of Denmark are very much similar to that of the Upper Danian of Scandinavia, but with certain forms peculiar to each.

Brotzen gave a Zealandian age for the Paleocene of Sweden and the Lower Paleocene of Denmark and a Thanetian age for the Upper Paleocene of Denmark. A comparison of Brotzen's fauna with that of the type Montian reveals a marked dissimilarity, only few stratigraphically insignificant forms are common, while definite Thanetian beds in France and Belgium contain well known foraminifera from the Swedish-Danish Paleocene. This added to the fact that the Swedish-Danish lower Paleocene is very similar to that of the type upper Danian, would mean an earlier Tertiary transgression depositing the Scandinavian Lower Paleocene (Zealandian), before the type Montian, with a slight vertical extension to the base of the Thanetian.

Egypt.—The problem of the Cretaceous-Tertiary boundary is not satisfactorily solved in most regions, owing to the insignificant and indecisive character of the type Montian and type Danian faunas, and the consequent difficulty of assigning one formation or the other to Danian or Montian. This has led many authors in different countries to resort to the term "Dano-Montian." To this chronological combination were referred formations which have transitional faunas between the "Cretaceous" Danian and the well accepted Tertiary Montian. The same rule was also observed in Egypt, but after this study, it is possible to specify the individual characters of the two stages Montian and Danian, and to group them both at the base of the Tertiary Paleocene.

Although some authors have previously referred to the presence of Montian deposits in Egypt and recorded some of its fauna, the stage as a biostratigraphic unit remained undefined and uncorrelated. The microfauna of the Montian of Egypt ranges to the overlying Thanetian or the underlying Danian, with no species peculiar to it. Some may appear to be so restricted in certain areas. In spite of this handicap, it is possible to draw the limit between the Montian and the enclosing stages through observation of species ranges in the stratigraphic sequence. The lower boundary or the advent of Montian is marked by the first appearance of the following species, which could also extend to Thanetian or even to Eocene: *Nummulites deserti* de la Harpe, *Operculina libyca* (Schwager), *Discocyclina nudimargo* (Schwager), *Cibicides rigidus* (Schwager), *Elphidium africanum* Le Roy. The following species extend to the Montian from the underlying Danian: *Eponides candidula* (Schwager), *E. lotus* (Schwager), *Sigmoilina proboscidea* (Schwager), *Robulus isidis* (Schwager), *R. mellahensis* var. *obesus* Nakkady, *Anomalina umbonifera* (Schwager), *Cibicides praecurosrius* (Schwager), *Glandulina caudigera* (Schwager), *Cancris auricula* (Fichtell and Moll), *Globigerina pseudobulloides* Plummer, *G. triloculinoides* Plummer, *G. esnaensis* Le Roy, *G. quadrata* White, *G. cretacea* d'Orb. var. *esnehensis* Nakkady, *G. bulloides* d'Orb., *Globorotalia crassaformis* (Galloway & Wissler); *G. crassata* (Cushman) var. *aequa* Cushman & Renz, *G. angulata* (White), *G. simulatilis* (Schwager), *Rotalia rigida* (Schwager), *Valvulineria scrobiculata* (Schwager), *V. esnehensis* Nakkady.

The upper limit of the Montian is drawn at the appearance and flooding of the Alveolines: *Alveolina oblonga* d'Orb., *A. lepidula* Schwager, and *A. ellipsoidalis* Schwager. These forms occur together with *Triloculina oblonga* (Montf.), *T. trigonula* (Lmk.), and *Heterostegina ruida* Schwager in the "*Alevolina* horizon" of Zittel's "Libysche-Stufe."

The biostratigraphic characters of the Montian, as described above, are best typified by the *Eponides lotus* subdivision of Le Roy's Unit II (1953), of the Maqfi section (Farafra Oasis), considered hitherto as Lower Eocene, but assigned here as the true representative of Montian age in Egypt. Compared with the fauna of the underlying Danian, the two have many important elements in common, forms which constitute the major part of that fauna. Actually a good part of the Danian fauna passes imperceptibly into the Montian; the only change is the introduction of larger foraminifera (*Nummulites*, *Discocyclina* and *Operculina*), which appeared in the warm shallowing regressing seas of the Montian. In addition, there is *Cibicides rigidus* and *Elphidium africanum*.

There are at least 35 species common to the Montian and the Danian of Egypt; 16 of which are exclusive to these two ages in this region and do not extend down to Senonian.

Correlation with other regions.—The "scanty" type-Montian fauna has very little in common with the Egyptian Montian fauna. *Cibicides praecursorius* and *Globorotalia velascoensis* are the only two correlating species. Both forms extend down into the Danian of Egypt but are restricted to Montian in the type area.

The Egyptian Montian has a similar relationship with the Zealandian of Sweden, and Denmark. Only *Globigerina triloculinoides*, *G. pseudobulloides* and *Anomalinoides dancia* being common to both. These three forms are also known from the type Danian.

The Montian fauna of Egypt may be correlated with the Hot Spring formation in the Caucasus, the so-called Lower Tertiary. They have in common the following species: *Nonionella insecta*, *Eponides lotus*, *Cibicides praecursorius*, *Globigerina pseudobulloides*, *G. triloculinoides*, *Globorotalia crassaformis*, *G. simulatilis*, *G. velascoensis; G. membranacea*, *Ramulina globulifera*, *Anomalina grosserugosa*. Of these species, the first three only are exclusive to the Caucasus "Lower Tertiary." The remainder, like those of Egypt, extend down to Danian or Senonian.

The "Dano-Montian" episode in the geological history of the Middle East regions, as exhibited in the works of Henson (1938), Grimsdale (1951), Reiss (1952, 1956) and others, shows almost the same smaller foraminiferal species and ranges as in Egypt. Moreover, most of Reiss, "Danian and Paleocene" species occur also in the Danian of Egypt, as defined in this work. They occur also in the Danian of the Caucasus, the Velasco of Mexico, as well as in the Danian type locality. It is interesting, however, to note that Reiss has found that in Israel "within the Danian-Paleocene" complex, two main divisions may be distinguished: a lower part characterized by abundant *Globigerinae* and *Discorbidae*, and an upper part characterized by the abundance of *Globigerinae* and *Globorotaliae*. These conclusions coordinate well with earlier work of the author (Nakkady, 1951) described as a *Globotruncana* zone, a "Buffer" zone, and a *Globorotalia* zone in the Mesozoic-Cenozoic transition of Egypt.

The Egyptian "Buffer" zone, of Danian age, is located between the underlying *Globotruncana* zone (of Maestrichtian age) and the overlying *Globorotalia* zone. The fauna has almost no *Globotruncana* or *Globorotalia*, but has a rich *Globigerina* fauna of the Danian or late Maestrichtian types; together with some well known forms as: *Gaudryina pyramidata* Cushman, *G. rugosa* d'Orb., *Verneuilina cretacea* Reuss, *Spiroplectammina carinata* (d'Orb.), *Anomalina pseudoacuta* Nakkady, *A. umbonifera* (Schwager), *Anomalinoides danica* (Brotzen). The *Globorotalia* zone contains a number of *Globorotalia* species in abundance: *G. angulata* (White), *G. crassaformis* (Galloway & Wissler), *G. velascoensis* (Cushman), *G. crassata* var. *aequa* Cushman & Renz, *G. simulatilis* (Schwager), *G. membranacea* (Ehr.). This fauna had its beginning in the Danian, and it has much in common with the Danian of the Caucasus, Velasco, and the type Danian. It extends more or less to the overlying Montian to become associated with the new distinguishing elements of that age.

Because of the uncertainty over the Danian and Montian, Sigal (1949), ten Dam & Sigal (1950) and Hilly & Sigal (1951), referred the early Paleocene deposits of Algeria to Dano-Montian. Compared with the Montian fauna of Egypt, the Algerian Dano-Montian fauna has only 4 species in

common: *Globigerina pseudobulloides, G. triloculinoides, Globorotalia simulatilis, G. velascoensis.* The fauna reported by Sigal (1949) is of particular interest for correlation. With no exception, all the 9 species identified are known from the North American upper Midway. *Hoglundina scalaris* (Franke), *Allomorphina halli* Jennings, and *Globigerina pseudobulloides* Plummer, are also well known from the Zealandian (Lower Paleocene). It seems that this "Dano-Montian" fauna of Algeria should be correlated with the upper Midway of the Gulf Coast and its equivalent, the Zealandian of Sweden, both of late Lower Paleocene age.

The Montian fauna of Egypt shows some affinity with the upper Midway of the Gulf Coast. The following species are common to both but are known also from the basal Midway and the Egyptian Danian: *Nonionella insecta, Eponides lotus, Cibicides praecursorius, Globigerina pseudobullides, G. triloculinoides, Globorotalia crassata* var. *aequa, Globorotalia membranacea.* None of the exclusive upper Midway species or the specific Egyptian Montian fauna have been found in common. The upper Midway (Wills Point, Naheola, and equivalent formations in the Gulf Coast Region) have been correlated by Brotzen (1948) with the Scandinavian Lower Paleocene. The basal Midway (Kincaid and equivalent formations) were correlated with the type upper Danian. The two American Paleocene stages have at least 60 restricted species in common. Of these there are present in the two corresponding Egyptian stages (Danian and Montian) the 7 species mentioned; and in the Egyptian Danian alone, the following 9 well known species: *Loxostomum applinae, Siphogenerinoides eleganta, Gaudryina soldadoensis, Ellipsonodosaria midwayensis, Robulus pseudomammiligerus, Marginulina tuberculata, Pleurostomella alternans, Nodosaria vertebralis, Epistominella obtusa.* From a comparison of the ranges of the common species in the two basins (Egypt and the United States Gulf Coast Region) it appears that a good part of the important index species have comparable ranges. Seven species have the same Dano-Montian range in the Midway and Egypt; and nine others have similar ranges but are confined to the Danian in Egypt.

The foraminiferal fauna of the Paleocene of California, is reported in the works of Laiming (1941), Martin (1943), Israelsky (1951, 1955) and others. These faunas were studied together with a section provided by the Standard Oil Company of California, from the west side of San Joaquin Valley (Cheyney Ranch Well No. 1) including the type Cheyneyan stage of Goudkoff and the overlying Plata formation. These faunas have nothing at all in common with the fauna which survived the late Lower Paleocene of Egypt. An interesting assemblage is common, however, with the earliest Egyptian Paleocene (Danian), including some well known index species: *Loxostomum applinae, Robulus pseudomammiligerus, Pleurostomella alternans, Spiroplectoides clotho, Dentalina megalopolitana, Gaudryina pyramidata, Clavulina parisiensis, Saracenaria triangularis, Marginulina tuberculata, Nodosaria affinis, Gumbelina globulosa, Bulimina spinata, Gyroidina subangulata.* The respective ranges of these common species in the two basins (Egypt and California) are shown on Table 1. It appears that the Californian examples had wider ranges than their Egyptian kins. Of these 13 common Californian-Egyptian species, ten are known also from the Danian of the American Gulf Coast Region (basal Midway and Velasco) and five range to the upper Midway. Exclusive Californian Paleocene species, *i.e.* those which do not range into older strata in California, are known also from Danian horizons. *Loxostomum applinae, Calvulinoides aspera, Robulus midwayensis, Marginulina tuberculata, Pleurostomella alternans,* and *Epistominella velascoensis* are well known elements in the Danian of the U. S. Gulf Region. It seems likely that the California Paleocene can be tentatively correlated with the Danian of Egypt and the basal Midway.

DANIAN

The type area for the Danian stage is in Denmark, where the Lower Danian "Bryozoan limestone" unconformably overlies the upper Senonian "White Chalk." Typically, this unit is represented in Stevns Klint and the Isle of Mors. However, near Voxlex in Jutland, Jessen & Odum (1923) noted the

TABLE 1.—STRATIGRAPHIC RANGES OF FORAMINIFERAL SPECIES WITHIN THE UPPER SENONIAN-LOWER PALEOCENE OF EGYPT AND THEIR DISTRIBUTION IN THE FOUR BASINS
(T: Tethys, N: North European Basin, A: Atlantic American and P: Pacific American Basins)

Rangesin Egypt				Species	Senonian												Lower Paleocene							Ranges in the Four Basins				
					Lower Senon.				Campan.				Maestr.				Danian			Montian									
Campanian	Maestricht.	Danian	Montian		T	N	A	P	T	N	A	P	T	N	A	P	T	N	A	T	N	A	P	Low. Senon.	Campanian	Maestricht.	Danian	Montian
			—	Nummulites deserti																								
			—	Discocyclina nudimargo																								
			—	Cibicides rigidus																								
			—	Cancris auricula																								
	—	—	—	Eponides candidula																	—							X
	..	.....	....	Sigmoilina proboscidea																								X
			—	Nonionella insecta															—	—							X	X
	—	—		Nodosaria longiscata															—	—	—						X	X
	—	—	—	Eponides lotus															—	—	—						X	X
			....	Verneuilina luxorensis																							X	X
				Loxostomum applinae													—		—	—	—	—					X	X
				Siphogenerinoides eleganta															—								X	X
				Bulimina quadrata															—								X	X
	—			Bulimina cacumenata															—								X	X
			—	Robulus mellahensis, var. obesus																							X	X
				Gaudryina soldadoensis															—								X	X
	—			Ellipsonodosaria paleocenica															—								X	X
				Ellipsonodosaria midwayensis															—								X	X
	—		—	Cibicides praecursorius															—	—	—						X	X
	—			Dentalina mucronata															—								X	X
				Bulimina inflata													—		—								X	X
	..		—	Anomalina luxorensis																							X	X
	...		—	Robulus isidis																							X	X
	—			Spiroplectammina carinata													—		—								X	X
				Robulus pseudomammiligerus													—		—								X	X
				Palmula woodi																							X	X
	..			Alabamina midwayensis													—	—	—	—							X	X
	—			Eponides umbonatus													—		—	—							X	X
				Marginulina tuberculata															—	—	—						X	X
	..		—	Globigerina pseudobulloides													—		—	—	—						X	X
			—	Globigerina triloculinoides													—	—	—	—	—						X	X
			—	Globigerina esnaensis																							X	X
		—	—	Globorotalia crassata, var. aequa													—		—	—							X	X
		—	—	Globorotalia angulata													—		—	—							X	X
		—	—	Globorotalia simulatilis													—		—	—							X	X
		—	—	Globorotalia velascoensis													—		—	—	—						X	X
	...			Lenticulina gussensis													—		—	—							X	X
	..			Pleurostomella alternans													—		—	—							X	X
	..	...	—	Globorotalia crassaformis											—		—		—	—							X	X
				Spiroplectoides clotho											—	—	—		—								X	X
—	—	—		Anomalina pseudoacuta									—				—										X	X
		—		Bulimina rugifera									—				—		—								X	X
		—		Frondicularia wanneri																							X	X
		—		Eponides lunatus											—		—			—							X	X
	—	—	—	Rotalia rigida											—		—			—							X	X
	—	—	—	Anomalinoides danica											—		—	—		—							X	X
.....	..	—	—	Anomalina umbonifera													—	—		—							X	X
	—	—		Dentalina megalopolitana						—	—				—	—			—							X	X	X
		—		Nodosaria vertebralis						—					—	—			—	—	—					X	X	X
	—	—	—	Ramulina globulifera					—				—		—	—			—	—						X	X	X
		—	—	Globorotalia membranacea						—			—		—	—			—							X	X	X
		—		Alabamina obtusa					—				—		—	—			—							X	X	X
—	—	—		Saracenaria navicula		—				—			—		—	—			—	—	—					X	X	X
—	—	—		Ammodiscus incertus		—				—			—		—	—			—	—	—					X	X	X
—	—	—		Gaudryina pyramidata						—	—		—		—	—			—							X	X	X
—	—	—		Gaudryina rugosa	—	—			—	—			—		—	—			—							X	X	X
		—		Dorothia bulleta			—			—			—		—	—			—							X	X	X
	—	—		Clavulina parisiensis						—			—		—	—			—	—	—					X	X	X
	—	—		Robulus rotulata	—	—	—			—			—		—	—			—		—					X	X	X
—	—	—		Saracenaria triangularis						—			—		—	—			—							X	X	X
	—	—		Siphogenarina esnehensis				—		—			—		—	—			—							X	X	X
—	—	...		Palmula rugosa	—	—	—			—			—		—	—			—		—					X	X	X
	—	—	—	Valvulineria scrobiculata	—	—	—			—			—		—	—			—		—					X	X	X
—	—	—		Nodosaria affinis	—	—	—			—			—		—	—			—		—					X	X	X
	—	—	—	Nodosaria latejugata		—				—			—		—	—			—	—	—					X	X	X
—	—	..		Gumbelina globulosa	—	—	—	—		—	—		—		—	—			—		—					X	X	X
	—	—		Bulimina spinata				—			—				—	—					—					X	X	X
	—	—		Loxostomum plaitum			—			—			—		—	—			—	—						X	X	X

Ranges in Egypt				Species	Senonian												Lower Paleocene								Ranges in the Four Basins				
					Lower Senon.				Campan.				Maestr				Danian			Montian									
Campanian	Maestricht.	Danian	Montian		T	N	A	P	T	N	A	P	T	N	A	P	T	N	A	T	N	A	P	Low. Senon.	Campanian	Maestricht.	Danian	Montian
				Frondicularia archiaciana																				X	X	X	X	X
				Ramulina aculeata																				X	X	X	X	X
				Pullenia quaternaria																				X	X	X	X	X
				Pullenia quinqueloba																				X	X	X	X	X
				Globigerinella aspera																				X	X	X	X	X
				Gyroidina florealis																				X	X	X	X	X
				Valvulineria esnehensis																				X	X	X	X	X
				Gyroidina girardana																				X	X	X	X	X
				Gyroidina subangulata																				X	X	X	X	X
				Globigerina bulloides																				X	X	X	X	X
				Anomalina grosserugosa																				X	X	X	X	X
				Allomorphina trigona																				X	X	X	X	X
				Glomospira charoides																				X	X	X	X	X
				Pseudonodosaria larva																				X	X	X	X	X
				Spiroplectammina excolata																				X	X	X	X	X
				Vulvulina colei																							X	X
				Bolivinoides velascoensis																							X	X
				Rectoglandulina caudigera																							X	X
				Globigerina mckannai																							X	X
				Globigerina quadrata																							X	X
				Valvulineria brotzeni																							X	X
				Gaudryina laevigata																							X	X
				Verneuilina cretacea																							X	X
				Palmula reticulata																							X	X
				Glandulina laevigata																							X	X
				Loxostomum limonense																							X	X
				Cibicides abudurbensis																							X	X
				Discorbis pseudoscopos																							X	X
				Pseudoclavulina clavata																				X			X	X
				Marssonella oxycona																				X			X	X
				Nodosaria paupercula																				X			X	X
				Nodosaria zippei																				X			X	X
				Bolivinoides decoratus																				X			X	X
				Globigerina cretacea																				X			X	X
				Gyroidina nitida																				X			X	X
				Eouvigerina aegyptiaca																				X			X	X
				Clavulinoides aspera																				X			X	X
				Rugoglobigerina reicheli																							X	
				Reussella aegyptiaca																							X	
				Lenticulina reniformis																							X	
				Bolivinoides rhomboidea																							X	
				Bolivinoides peterssoni																							X	
				Pseudotextularia varians																							X	
				Frondicularia esnehensis																							X	
				Siphogenerinoides oveyi																							X	
				Ventilabrella carseyae																							X	
				Allomorphina navarroana																							X	
				Marginulina silicula																							X	
				Globotruncana gansseri																							X	
				Ellipsonodosaria stephensoni var. speciosa																							X	
				Globotruncana aegyptiaca																							X	X
				Spiroplectammina dentata																							X	X
				Clavulinoides trilatera, var. concava																							X	X
				Bulimina prolixa																							X	X
				Robulus pondi																							X	X
				Dentalina basiplanata																							X	X
				Gumbelina excolata																							X	X
				Planoglobulina acervulinoides																							X	X
				Bolivina incrassata																							X	X
				Ellipsonodosaria alexanderi																							X	X
				Globotruncana ansarii																							X	X
				Globotruncana contusa																							X	X
				Globotruncana caliciformis																							X	X
				Globotruncana torensis																							X	X
				Globotruncana globigerinoides																							X	X
				Dorothia conulus																				X	X	X	X	
				Spiroplectammina cretosa																				X	X	X	X	
				Trochammina diagonis																				X	X	X	X	
				Robulus pseudosecans																				X	X	X	X	

Ranges in Egypt				Species	Senonian												Lower Paleocene							Ranges in the Four Basins				
					Lower Senon.				Campan.				Maestr.				Danian			Montian								
Campanian	Maestricht	Danian	Montain		T	N	A	P	T	N	A	P	T	N	A	P	T	N	A	T	N	A	P	Low. Senon.	Campanian	Maestricht.	Danian	Montian
	—	—		Bolivina decurrens		—							—	—										×	×	×		
	—			Bronnimanella plummerae			—				—				—									×	×	×		
	—	..		Palmula suturalis			—				—				—									×	×	×		
		—		Dentalina inornata	—	—			—	—				—										×	×	×		
..	—	—		Dentalina legumen	—	—	—		—	—	—			—	—									×	×	×		
—	—	—		Frondicularia goldfussi			—				—	—			—	—								×	×	×		
		—		Frondicularia inversa		—	—		—	—	—			—	—									×	×	×		
	—			Frondicularia linearis			—				—				—									×	×	×		
	—	—		Frondicularia lanceola			—				—				—									×	×	×		
	—	—	....	Lagena globosa		—				—				—										×	×	×		
		—		Bolivinopsis rosula			—				—				—									×	×	×		
—	—			Gumbelina striata			—		—		—				—									×	×	×		
	—			Pseudouvigerina cretacea			—				—		—		—									×	×	×		
	—			Bulimina murchisoniana	—	—			—	—	—			—	—									×	×	×		
—	—	—	....	Cibicides multifaria																				×	×	×		
—	—	..		Buliminella carseyae			—				—				—									×	×	×		
	—			Buliminella cushmani			—				—				—									×	×	×		
—	—			Neobulimina canadensis			—				—				—									×	×	×		
	—			Virgulina tegulata	—	—			—	—			—	—										×	×	×		
	—			Pullenia cretacea		—				—				—										×	×	×		
..	..	—	..	Stenosiöina pommerana		—				—			—	—										×	×	×		
..	....			Globorotalites micheliniana			—		—	—				—										×	×	×		
—	—			Globotruncana rosetta			—		—	—		—	—	—		—								×	×	×		
	—			Globotruncana arca	—				—				—											×	×	×		
				Globotruncana pseudoforniçata																									
—	—			Globotruncana lapparenti	—		—		—		—				—									×	×	×		
—	—			Globotruncana esnehensis																				×	×	×		
—	—			Globotruncana ventricosa			—				—				—									×	×	×		
		—		Globotruncana cretacea			—	—			—				—									×	×	×		
—	—			Ventilabrella eggeri			—																	×	×	×		
		—		Pseudotextularia elegans					—				—	—										×	×	×		
—	..			Ammobaculites taylorensis							—														×			
—	....	..		Vaginulina taylorana							—														×			
	...			Ellipsonodosaria exiliis							—														×			
—	—			Globotruncana sudrensis							—														×			
—				Pseudogaudryinella capitosa			—				—														×			
	..	—		Lenticulina ovalis		—				—															×			
	—			Gumbelina reussi			—				—														×			
—	—			Nodosarella gracillima			—				—														×			

presence of a transitional layer between the Bryozoan limestone and the Maestrichtian White Chalk. In the lower part of this transitional deposit there is a characteristic Senonian fauna, whereas the fauna of the upper part is a mixture of species that are common to Senonian and Danian—a single Senonian species and a majority of exclusively Danian forms, including *Tylocidaris vexilifera*, *Agiope faxensis* and *Echinochorys sulcatus*. Just which of the Danish formations are to be included within the type upper Danian or are to be attached to the overlying Montian has been a controversial subject among Danish geologists. It is not the object of this work to become involved in that subject (Ravn, 1925).

The type microfauna.—The type Danian microfauna occurring in the "Bryozoan" and "Coccolith" chalk and the overlying "*Crania*" limestone is separated from the *Pseudotextularia elegans* fauna of the underlying uppermost Maestrichtian by a small lacuna. The fauna exclusive to the type formations seem to be stratigraphically insignificant, but the associated wider-ranging species are valuable elements in the Danian fauna of many regions. Such species as *Nonion graniferum*, *Globigerina triloculinoides*, *G. compressa*, *G. pseudobulloides*, *G. cretacea*, *Bolivina primatumida*, *Alabamina midwayensis*, *Loxostomum applinae*, *Karreria fallax*, *Bolivinita selmaensis*, *Anomalinoides danica*, *Coleites reticulosus*, *Globigerinella aspera*, *Citharina plumoides*, *Eponides lunata*, *Valvulineria laevis* and *Parella lens* are apt to be encountered in most Danian formations; they can be of some stratigraphic value though not exclusive to the age. A substantial advance in our knowl-

edge of the Danian microfauna came as a result of the works of Keller (1936), Subbotina (1936) and Glaessner (1937), who recognized a rich microfauna associated with a Danian macrofauna in the deposits of the western Caucasus: *Echinocorys sulcatus* Goldf., *Coraster villanovae* Cott., *Coraster munieri* Seunes, *Exogyra semilis* Pusch., *Gryphaea pitcheri* Mort., "*Nautilus*" *cassinianus* Foord & Crick, "*Nautilus*" *danicus* Schloth. The subsequent works of Keller (1939) and Wicher (1949) successfully correlated that fauna with the rich fauna of the Danian Velasco of Mexico and added to our knowledge about the character of the Danian fauna.

The Danian fauna in the Scandinavian region has at least 14 known species exclusive to the Danian-Montian, against just one species exclusive to the Maestrichtian-Danian, and about 6 species which range throughout from Maestrichtian to Montian. These relationships support a Paleocene age for the Danian.

The Danian in Egypt.—The Danian is represented in Egypt by important deposits and a very characteristic fauna. As defined in this work, it should include all the formations and fauna lying between the upper surface of the *Globotruncana* zone (Nakkady, 1951), with the topmost extension of the *Globotruncana* species which reach this level, and the first appearance of a Montian fauna with *Nummulites deserti, Operculina libyca*, etc. It is necessary to emphasize the "true" appearance of this fauna, because occasionally big rock masses slide from this Montian horizon, settle among older strata, and cause stratigraphic confusion. An example of this feature is illustrated by the so-called Unit III of the Maqfi section (Le Roy, 1953)—a seven-foot massive crystalline limestone layer with a Montian fauna is enclosed from above and below by a shale with a Danian fauna.

The character of the Danian fauna of Egypt and its differentiation from the undisputed Cretaceous fauna of the Maestrichtian can be analyzed through 4 elements:

1. Species exclusive to the horizon.
2. Species passing from the horizon to the overlying Montian.
3. Species terminating at or near the Maestrichtian-Danian boundary.
4. Species ranging from Maestrichtian to Danian.

Many of the exclusively Danian species of Egypt, have wider ranges in other regions. They may range upwards to younger horizons: *Loxostomum applinae, Siphogenerinoides eleganta, Ellipsonodosaria midwayensis, Robulus pseudomammiligerus* and *Marginulina tuberculata*, which are known from both Danian and Montian of the United States Gulf Coast Region. They may range upward into Montian and downward into Senonian of other regions: *Spiroplectoides clotho, Bulimina rugifera, Eponides lunatus, Nodosaria vertebralis, Gyroidina subangulata, Dorothia bulleta, Allomorphina trigona* and *Ramulina aculeata*. A few are known only from older horizons in other regions: *Lenticulina reniformis, Dorothia conulus* and *Bolivinopsis rosula*. Few of the exclusively Danian species in Egypt are exclusive to Danian in other regions: *Vulvulina colei* of the Caucasus, *Alabamina obtusa* and *Gaudryina scldadcenis* in the lower Midway, and *Bolivinoides velascoensis* in the Velasco of Mexico. The species which pass in Egypt from Danian to Montian: like *Nonionella insecta, Eponides lotus, Cibicides praecursorius, Globigerina triloculinoides, G. pseudobulloides, Globorotaliae, crassaformis, crassata* vars. *aequa, angulata, simulatilis, membrancea, velascoensis*, and *Anomalinoides danica* have almost the same ranges in most other regions.

The sudden flooding of the Globorotaliae of this fauna and their domination over other members of the fauna, mark a conspicuous horizon in the Danian of all Egyptian sections. *Globorotalia* seems to be retarded in appearance in some sections with an expanded Danian "Buffer" zone (Nakkady, 1951). Said & Kenawy (1956) observed this retardation in one of their Sinai sections and therefore regarded most of the planktonic forms as of negligible value in constructing zones. In their failure to find a plausible explanation for this retardation of *Globorotalia*, those authors draw a "*Truncorotalia* surface" cutting diagonally through strata and time lines to demonstrate lack of chronologic significance. They also substi-

tute the many species of *Globorotalia* as a zone marker with *Neoflabellina jarvisi*. The writer has had a chance to examine types of *N. jarvisi* and to compare them with the Said & Kenawy hypotypes of that species as well as those of their *N. rugosa* from the Maestrichtian. The Maestrichtian specimens, as well as those which the writer examined from other sections, do not differ from the Paleocene ones and the form cannot be accepted as a time marker. In contrast, the stratigraphic value of *Globorotalia* in the Paleocene has been well established by many authors: Reiss (1952, 1956), Grimsdale (1951), Subbotina (1936, 1939), Keller (1936), Glaessner (1937), Wicher (1946), Loeblich & Tappan (personal communication), and Nakkady (1949, 1951). The retardation in the appearance of *Globorotalia* in some sections does not minimize its stratigraphic value. In Egypt, variation in the appearance of *Globorotalia* in the different sections is negligible in comparison to the distance. Also, it is believed that variations in the *Globigerina* zone do not imply unconformity, such as Reiss (1956) suggests, between Maestrichtian and Dania. A considerable portion of the Maestrichtian fauna extends into the overlying zone and some of the globigerines of the *Globigerina* zone are also present at some localities in the underlying *Globotruncana* zone.

Comparing the characteristic Danian fauna with the Cretaceous fauna which stops near the Maestrichtian-Danian boundary, a conspicuous change is observed. At this boundary all flourishing species of *Globotruncana*, together with other conspicuous elements of the upper Maestrichtian fauna, suddenly disappear. Such well known index fossils as *Spiroplectammina excolata* (Cushman), *Bronnimanella plummerae* (Loetterle), *Reussella aegyptiaca* Nakkady, *Bolivinoides peterssoni* Brotzen, *Pseudotextularia varians* (Rzehak), *Allomorphina navarroana* Cushman, *Marginulina silicula* (Plummer), *Globotruncana gansseri* Bolli, *Robulus pondi* Cushman, *Gumbelina excolata* Cushman, *Planoglobulina acervulinoides* (Egger), *Rugoglobigerina reicheli* Bronnimann, *Frondicularia archiaciana* d'Orb., *Frondiculania linearis* Franke, *Pleudovigerina cretacea* Cushman, *Bulimina cushmani* Sandidge, *Neobulimina canadensis* Cushman & Wickenden, *Virgulina tegulata* Rss., *Gumbelina striata* (Ehr.), *Globotruncana arca* (Cushman), *G. aegyptiaca* Nakkady, *G. esnehensis* Nakkady & Osman, *G. cretacea* Cushman, *Pseudotextularia elegans* (Rzehak), and *Ventilabrella eggeri* Cushman are no longer observed.

Species initiated with the Danian, are found to exceed in number the species that are common to Maestrichtian and Danian. These latter forms are either stratigraphically insignificant, as most of them are, though having long ranges (in many cases from Montian to lower Senonian) or their survival is naturally expected in such a basin of continuous deposition.

Correlation with other regions.—Compared with the Danian in the type area, the Danian of Egypt is found to contain the following common forms: *Alabamina midwayensis*, *Globigerina triloculinoides*, *G. pseudobulloides*, *Loxostomum applinae*, *Eponides lunatus*, *Anomalinoides danica*, and *Globigerina cretacea*. Four of these well known species have the same ranges in the two regions; *Alabamina midwayensis*, *Loxostomum applinae* and *Eponides lunatus* are confined to Danian only in Egypt.

The Danian fauna of Egypt is well represented in the Danian of the Caucasus; several species are common to the Danian of the two regions. There are, however, some Egyptian Danian or Danian and Montian species, such as *Loxostomum applinae*, *Nonionella insecta*, *Eponides lotus* and *Cibicides praecurscrius*, that are confined to Montian in the western Caucasus. Egyptian species which form the greatest part of the Danian fauna in Egypt, range in the western Caucasus through Danian and Montian; another support for a Tertiary position for the Danian in general.

A similar picture to the Egyptian Danian is offered by the so-called "Danian and Paleocene" of Israel. The lower part contains abundant *Globigerina;* these same forms also flood the upper part which is marked by the sudden flooding of *Globorotalia*. Out of 41 species mentioned in this "Danian and Paleocene" horizon, at least the more important 23 are well represented in the Danian of Egypt an indication of a similar Danian age for the Israeli horizon.

The so-called "Dano-Montian" or "Paleo-

cene" of Algeria, can be correlated with the upper Midway of the U. S. Gulf Region or the Zealandian of Sweden. In addition, it contains two exclusively Egyptian Danian species: *Marginulina tuberculata* and *Robulus pseudomammiligerus*, as well as four Egyptian Danian-and-Montian species: *Globigerina pseudobulloides*, *G. triloculinoides*, *Globorotalia velascoensis*, and *G. simulatilis*.

The fauna of the Egyptian Danian is well represented in the United States Gulf Coast formations and particularly in the Midway. The Egyptian Danian can be readily correlated with the basal Midway.

Seven species have almost the same Dano-Montian range; three are exclusive to Danian in both areas. Twelve species extend to the upper Midway but are confined to Danian in Egypt; one extends upward to Montian in Egypt but remains only in the lower Midway of the Gulf Region. Four species have wide ranges from upper Midway to Senonian, another four do not reach the Midway from the Senonian in that region, and two are exclusively in upper Midway.

The Velasco shale of the Tampico Region of Eastern Mexico contains a fauna which correlates with that of the Danian of Egypt. There are at least 30 well known common species which show remarkable coincidence of their ranges in this episode of the two regions. Three of the 4 Egyptian Danian species which occur also in the Chicontepec of Mexico are of little stratigraphic significance. The fourth species, *Loxostomum applinae*, is known also to occur in Danian horizons in other regions, e.g. the type Danian and the lower Midway of the United States Gulf Coast.

The Danian fauna of Egypt finds ample resemblance in the "Paleocene" of California. Of the 13 Egyptian-Californian common species, five are exclusively in Egyptian Danian elements and the rest range more-or-less to older Senonian but not to younger Montian. The "Paleocene" of California could also be tentatively correlated with the basal Midway.

Summary.—From this brief survey, it appears that the Danian of Egypt can be compared with contemporaneous deposits in many regions. It is particularly close to the Danian of the Caucasus, the "Danian and Paleocene" of Israel, the lower Midway of the United States Gulf Coast, and the Velasco of Mexico. With a presentation of its biostratigraphic characters and tracing of its inter-regional relations, there is no longer much reason for controversy about the presence of Danian in Egypt or elimination of the term from the stratigraphy of the Near East (Tromp, 1949).

DANIAN IN THE STANDARD STRATIGRAPHIC SCALE

The dividing line between Cretaceous and Tertiary has been a controversial subject in most countries, particularly for those regions which show some indications of continuity of deposition. Various pertinent features have been argued and disputed in the past, but the evidences set forward in this study seem to be convincing for a Tertiary age for the Danian, at the base of Paleocene. The dividing line separating major stratigraphic divisions as between groups or systems, *e.g.* Mesozoic-Cenozoic or Cretaceous-Tertiary, had best be chosen in a position to mark substantial differences of fauna. In parts of the world the ammonites range to the end of the Mesozoic but end abruptly at the top of the Maestrichtian. A similar picture is found also among the microfauna; *Globotruncana* and associated upper Senonian elements exhibit a sharp termination where the Maestrichtian upper surface is drawn. It is true that in certain regions, like the North European facies, *Globotruncana* does not reach its maximum development this late but dies out mainly at the Campanian-Maestrichtian boundary. In this area, however, the substituting upper Maestrichtian elements such as *Pseudotextularia elegans*, *Palmula reticulata*, and *Bolivinoides petersoni* are almost equally distinctive.

A substantially different fauna on the other side of the boundary, that is in the Lower Danian, contains a meager portion of the rather insignificant survivors, which persist weakly for some time before dying out completely. The major portion is made out of the newly-appearing Tertiary life which starts unimpressively at first but dominates an undisputable Tertiary fauna, similar to the Montian, by Middle and Upper Danian time.

Between these two substantially different

faunas, a sharp line could be safely installed to mark the end of a dying era, the Mesozoic, and the beginning of a new one, the Cenozoic. Almost everywhere in the world (Scandinavia, Caucasus, Middle East, Egypt, Algeria, United States Gulf Coast, and Mexico) the distinction between Danian and Maestrichtian (paleontological as well as stratigraphical) is greater than that between Danian and Montian. Even in regions where deposition has been continuous throughout the Mesozoic-Cenozoic transition, (as in some parts of Egypt) this relationship can be demonstrated. In some regions (Algeria and the Middle East) it is difficult to separate the Danian from the Montian and the formations have been collectively called "Dano-Montian" or "Danian and Paleocene." Relationships between the faunas of the two lower Paleocene divisions, Danian and Montian (Crania limestone and lower Zealandian of Scandinavia, lower and upper Midway of the United States, Tsitse and Hot Springs formations of the Caucasus, etc.) are too closely similar to be contrasted effectively.

MAESTRICHTIAN

The type locality for the Maestrichtian is near Maestricht in the Netherlands province of South Limburg. The Maestricht Chalk, a neritic deposit of the North European Cretaceous sea, has yielded a rich well preserved microfauna, that has been made known through the works of Reuss (1851, 1861), Raadshooven (1940), Schijfsma (1946), Hofker (1949), Visser (1951), and others. It contains such world famous species as *Bolivinoides peterssoni, Palmula reticulata, Pseudotextularia elegans, Bolivinoides dracomiliaris, Bolivina incrassata, Stensiöina pommerana, Bolivina decurrens, Bolivinoides paleocenica*, etc., some of which are exclusive to the age and with such short ranges that they may be used to mark horizons within the Maestrichtian, locally. For example, *Palmula reticulata, Bolivina decurrens* and *Stensiöina pommerana* in Egypt mark a thin horizon at the top of the Maestrichtian. *Bolivinoides peterssoni* and particularly *Pseudotextularia elegans* are markers for the upper Maestrichtian in Scandinavia.

Although most of the Maestrichtian species are present also in the underlying Campanian in the type area (South Limburg), the later stage can be distinguished by the presence of some characteristic well known forms as *Palmula reticulata, Pseudovigerina cimbrica, Bolivinoides peterssoni, Pseudotextularia elegans, Loxostomum limonense*, and *Reussella tricarinata*. The type stage correlates well with contemporaneous formations in the neighboring regions of the North European Basin; most of the species are common to both.

There is no doubt but that many elements of this so-called North European facies are represented in the southern regions, where they have similar ranges. There is, however, a remarkable scarcity, almost absence, of *Globotruncana* from the North European fauna. The Maestrichtian of the Netherlands contains the last survivor of the genus in that region, *G. linnei* (d'Orb.), but this is little compared with the maximum development the genus attains in the southern regions.

The Maestrichtian in Egypt.—Our knowledge of the Maestrichtian of Egypt is more clear and less controversial than of other ages represented in this country. Maestrichtian formations are well represented in many parts. The so called "Upper Cretaceous Chalk" is partly Maestrichtian and so are the basal layers of the "Upper Esna shales " but only in the northern districts such as Sinai. The Egyptian microfauna is rich and representative; characteristic cosmopolitan species are present. Many are exclusive to the age, and some are markers of fixed horizons, while several also range to the underlying Campanian or overlying Danian. *Palmula reticulata, Eouvigerina aegyptiaca, Bronnimanella plummerae, Reussella aegyptiaca, Planoglobulina acervulinoides, Rugoglobigerina reicheli, Bolivina decurrens, Stensiöina pommerana*, and *Pseudotextularia elegans* distinguish the top layers of the stage and but few of them survived into the earliest Danian.

Globotruncana is well represented in the Egyptian Maestrichtian by several species. *G. gansseri* Bolli, which ranges near the upper central part of the stage; *G. arca* and *G. cretacea*, together with many other species have continued from Campanian. All representatives die out en masse at or be-

fore the end of Maestrichtian time. This limited range is shared also by various species of the other most flourishing genus *Gumbelina*.

Other Maestrichtian forms exclusive to the age in Egypt, or just surviving into the basal layers of the Danian are: *Bolivinoides decoratus, B. peterssoni, Allomorphina navarroana, Marginulina silicula, Pseudovigerina cretacea, Bolivina incrassata, Ventilabrella carseyae, Pseudotextularia varians, Loxostomum limonense, Virgulina tegulata, Bulimina murchisoniana* and *Siphogenerinoides oveyi*. The upper limit of the Maestrichtian in Egypt can be drawn at the mass disappearance of the most characteristic Cretaceous species which flourished at that time: all *Globotruncana*, and nearly all the Heterohelicidae (*Pseudotextulariae, Gumbelinae, Bolivinoidae, Ventilabrellae*, and *Siphogenerinoides*).

The lower limit of the age, its junction with the underlying Campanian, is not so distinctly marked. Many of the Campanian species continue with about the same intensity into Maestrichtian. It is possible to draw the line between the two ages on the basis of the first appearance of an assemblage of forms which are known to be exclusively Maestrichtian in many regions and which seem to conform with this rule in Egypt. The first appearance in the sequence of an assemblage containing such forms as *Bolivinoides peterssoni, Pseudotextularia varians, Ventilabrella carseyae, Globotruncana gansseri*, and *Loxostomum limonense*, marks a Maestrichtian age. In addition, there are some Egyptian Maestrichtian species of stratigraphical importance and numerical frequency, such as *Siphogenerinoides oveyi*, which is not known to range into Campanian.

The Maestrichtian in Egypt was tentatively zoned by Nakkady & Osman (1954) on the restricted ranges of some *Globotruncana* species. The zones are of local stratigraphic value for the sections sampled and may prove to be of some regional use in the future.

It has been noted that certain well known forms are restricted to the lower layers of the Maestrichtian sequence, whereas others constantly show up only in the upper layers of the several Egyptian sections examined. Because of this difference the following subdivisions are suggested:

1. The upper Maestrichtian is characterized by the presence of: *Palmula reticulata, Rugoglobigerina reicheli, Bronnimanella plummerae, Anomalinoides danica, Pseudotextularia elegans*, and *Stensiöina pommerana*.
2. The lower Maestrichtian is distinguished by: *Globotruncana contusa, G. gansseri, Pseudotextularia varians*, and *Anomalinoides plummerae*.

Correlation with other regions.—Compared with the Maestrichtian of the type area the Egyptian Maestrichtian shows a remarkable synchronism of ranges of some well known species. Others show wider ranges in the Dutch region.

The Egyptian fauna's close relationship with the Maestrichtian of Scandinavia and the French-Belgian Basin is readily apparent (Table 1).

Although most of the common Egyptian Caucasian Maestrichtian species have longer ranges in the Caucasus than in Egypt, some well known forms such as *Bolivina incrassata, Spiroplectammina dentata, Pseudotextularia varians, Globigerina cretacea, Marsonella oxycona, Gumbelina globulosa* and *Robulus rotulata* have almost the same ranges in the two regions.

Israel's Maestrichtian microfauna shows many of the same species and ranges as the Egyptian contemporaneous episode. The minor differences exhibited by certain ranges, which should naturally be expected between any two regions, may be narrowed in the future with more work.

The Algerian Maestrichtian shows a fauna comparable with the Egyptian one. *Pseudotextularia varians, Spiroplectammina dentata, Globotruncana contusa, G. caliciformis, G. arca* and *Gumbelina globulosa* have almost the same ranges in the two regions.

A comparison of the ranges of the Maestrichtian species common between the American Gulf Coast Region and Egypt reveals that a few forms which range into the Paleocene of the Gulf Region; most of the remaining species have the same ranges.

The Maestrichtian microfauna of Egypt correlates with that of the Tampico embayment of Mexico. The ranges of the stratigraphically important common species synchronize well in the two regions.

Trinidad faunas show a marked similarity

to the Egyptian material, especially in the ranges of *Globotruncana*. It is also worth mentioning that Trinidad's Paleocene faunas (Soldado and Lizard Springs) have some common species with the Egyptian Paleocene, with comparable ranges. Among these are: *Gaudryina soldadoensis*, *Siphogenerinoides eleganta*, *Globorotalia crassata*, var. *aequa*, *Globorotalia pseudomenardii* and *Spiroplectammina excolata*.

The ranges of Maestrichtian species common between California and Egypt make it appear that there was a remarkable similarity of faunal character during these episodes in these regions.

CAMPANIAN

The early upper Senonian episode derives its name from the type locality "Champagne," a small chain of hills near Cognac in the Aquitaine. Though the characteristic foraminifera of this stage in the type area is incompletely known, our knowledge of the microfauna representing the age is growing rapidly through contributions from contemporaneous formations in other regions. The character of the Campanian fauna of the nearest region to the type area, appears in the work of Marie (1941) on the *Belemnitella mucronata* chalk of the Paris Basin. This chalk is believed by Schijfsma (1946) to be of middle and upper Campanian age; he denies the presence of Maestrichtian in the Paris Basin. The "Craie de Meudon," the "Craie superieure de Reims," "Craie superieure d'Hardivillers," and the "Craie phosphatee de la Picardie," are considered to be all Campanian. It is on this concept that the Campanian fauna of that region is visualized here. Marie's judgment for a Maestrichtian age of the fauna he mentions in his works of 1937 may also be retained, for the "Craie de Meudon" can be Maestrichtian in part.

The Campanian of the North European Basin is best exhibited in the work of Schijfsma (1946), on the "Hervian" of South Limburg and the works of Brotzen (1936, 1945). The Hervian material, consisting of 91 species and varieties, shows an affinity to the Maestrichtian fauna, with 47–48 species in common. The Scandinavian Campanian also shows a strong relation to the Maestrichtian of its region. Of 52 species representing that Campanian, 38 occur also in the overlying Maestrichtian. The differentiation of Maestrichtian and Campanian deposits in these regions and in most other regions, is not as easy as the distinction between Maestrichtian and Danian. In the North European Basin, certain formaniferal species seem to be restricted to Maestrichtian, enabling the stratigrapher to draw the boundary line between the two stages. Such species as *Pseudotextularia elegans*, *Bolivinoides peterssoni*, *B. paleocenica*, *B. dracodraco*, *B. decorata gigantea* and *Parella lens* were found to qualify in most regions.

The Campanian in Egypt.—The formations that are known to pertain to this age in Egypt are widespread over many parts of the country: northern, central, and western Sinai; Abu Roash; Bahariya; Qoseir; Upper Egypt, Dakhla, etc. They are also varied in lithology, from chalks, phosphates, cherts, oyster limestones to sandstones and bone beds.

Its microfauna, though rich and varied, is hardly distinguishable from that of the overlying Maestrichtian. Only by careful analysis of the fauna and elimination of exclusively Maestrichtian elements can the age be assigned. In most cases, the fauna passes imperceptibly into Maestrichtian. There are some species of restricted or almost restricted Campanian range in Egypt: *Globotruncana sudrensis*, *G. lapparenti*, *G. ventricosa*, *Spiroplectammina dentata*, *S. cretosa*, *Bolivina monilifera*, *Ammobaculites junceus*, *A. taylorensis*, *Loxostomum cushmani* and *Nonionella austinana*, which can help in identification.

The Campanian fauna in Egypt is found to compare best with that of contemporaneous ages in the Caucasus, Middle East, United States Gulf Coast Region, Eastern Mexico, and California. The comparative study of their common faunas and species ranges helps to establish the age in Egypt and its inter-regional correlation.

The few important common Campanian species serve to correlate the formations in the western Caucasus with Egypt. Similar ranges are apparent. The Campanian fauna of Israel and Egypt displays remarkably similar species and ranges. The distribution of the Campanian fauna in the Taylor and Papagallos, of the United States Gulf Re-

gion and Tampico embayment and in the Campanian of California shows a conspicuous similarity of the ranges of the species that are common between those regions and Egypt during these episodes.

CONCLUSION

The results achieved by this study may be summarized as follows:

1. Gradual shifting of facies during transgressions and regressions was responsible for age and faunal differences of the formations observed in the different districts.

2. The biostratigraphic characters of the four upper Senonian-lower Paleocene ages in Egypt are defined and the boundary lines between them are drawn:

   a. The Montian is supposed to start with the appearance and flooding of *Nummulites deserti* and *Operculina libyca*, and to end where the *Alveolina* horizon of Zittel's Libyan begin.

   b. The Danian ends where the Montian fauna beings, and starts after the extinction of the last *Globotruncana* and the associated upper Maestrichtian exclusive elements.

   c. The Maestrichtian begins and the Campanian ends, with the appearance in the sequence of the non-Campanian, all-Maestrichtian assemblage: *Pseudotextularia varians*, *Bolivinoides peterssoni*, *Siphogenerinoides oveyi*, etc.

3. The Danian appears established in the Paleocene. Its controversial presence in Egypt is elucidated after being correlated with typical Danian formations.

4. Inter-regional correlation of the four ages was affected with typical formations through comparison of species and assemblages as well as ranges of these species. The Danian of Egypt was found to correlate with the Tsitse of the Western Caucasus, the "Danian and Paleocene" of Israel, the basal Midway of United States and the Velasco of Mexico. The Egyptian Maestrichtian correlates with the Maestrichtian in the type locality, Israel, the Navarro of United States, and the Mendez of Mexico. This wide inter-regional correlation suggests also that these regions must have had a similar geologic history during these episodes.

5. Nine upper Senonian-lower Paleocene sections from widespread districts in Egypt are correlated.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 2, P. 448–454, 2 TEXT-FIG., MARCH 1957

CHEMICAL COMPOSITION, MICROSTRUCTURE, AND AFFINITIES OF THE NEURODONTIFORMES

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ABSTRACT—The nature, morphology, geographic, geologic and ecologic distribution of these extinct tooth-like fossils is reviewed. X-ray and thin-section studies reveal that they have a minutely fibrous structure parallel to the long axis, and a composition approximating calcium metaphosphate. It is suggested that they represent a group of primitive vertebrates, perhaps related to the "jaw-like" Ordovician fossil *Archeognathus*.

HISTORICAL REVIEW

THE Neurodontiformes (Branson & Mehl, 1944) were first recorded by Kirk (1929) from the Middle Ordovician Harding sandstone of Colorado. Kirk illustrated a number of different forms of minute teeth, which he referred to as "conodonts," and noted their association with numerous "fish" plate fragments. Branson & Mehl (1933) described further specimens from the same formation and the same general area as those described by Kirk. They gave a comprehensive account of their external morphology, and introduced the term "fibrous conodonts" to refer to this group of tooth-like microfossils.

A number of later workers (*e.g.* Sweet, 1955) have studied the external morphology and stratigraphic distribution of these forms, which have proved to be valuable index fossils. No detailed description of the internal structure or chemical composition of these fossils has yet been published, however, and little serious attention has been devoted to a study of their zoologic affinities. This is all the more surprising, in view of the number of references which have interpreted them as the remains of the earliest known vertebrates. The purpose of the present paper is to describe the structure and composition of these fossils, to review the published data concerning their morphology and distribution, and to discuss their possible zoologic affinities.

It is a pleasure to record our thanks to Dr. George L. Clark of the University of Illinois for his help and advice with the X-ray studies here described, to Dr. A. K. Miller of the State University of Iowa for the loan of the holotype of *Archeognathus primus*, and to Dr. Walter Sweet of Ohio State University for the gift of a number of specimens of fibrous conodonts.

NATURE OF THE NEURODONTIFORMES

Morphology.—The recognition of the Neurodontiformes as a distinct group was contained in a description by Branson & Mehl (1933) of the "conodont" fauna of the Harding sandstone of Colorado. They described them as follows (1933, p. 22):

> In the first place these Harding conodonts constitute a very primitive group. The entire assemblage, with very few exceptions, represents a division very distinct from the great majority of conodonts although duplicating the latter in general form. This difference can at present be described best as "fibrous" structure rather than the apparently laminar arrangement of the substance of the ordinary type. The simple cones of the Harding split lengthwise rather than across as is the case among most of the distacodids. The group . . . is usually recognizable through the dull surface and amber colour, although some specimens have shiny surfaces. Perhaps the most characteristic feature of the primitive group is the fact that the basal surface is attached directly to the hard surface of the jaw support almost by ankylosis so that the great majority of the specimens retain fused to them a part of the jaw. They seem to lack entirely the basal excavation designated by Pander as the "pulp cavity" that is particularly evident among the ordinary distacodids. Typical mid-Ordovician conodont assemblages . . . have but a small representation of this primitive type. Such of them as are present seem to have progressed beyond the firm attachment for among none of them have we noted adhering sections of the mandibular bars.

So far as their external morphology is concerned the Neurodontiformes may be subdivided into the following broad groups:

Type 1: Simple recurved cones, which (*a*) may, or (*b*) may not bear a small number of minor denticles near the base.

a. Stereoconus, Mixoconus

b. Multioistodus

Type 2: More or less straight bars, with a series of denticles developed along the "oral" surface, e.g. *Coleodus, Neocoleodus, Trucherognathus,* and *Polycaulodus.* Both *Coleodus* and *Neocoleodus* have a "grooved" basal surface (Branson & Mehl, 1933, p. 24).

Type 3: More or less arched bars, with a series of denticles developed along the "oral" surface, e.g. *Chirognathus, Leptochirognathus, Erismodus, Curtognathus,* and *Cardiodella. Erismodus* has an elongated excavation on the aboral surface of the bar.

The following genera, usually included in the group, are here omitted: *Ambolodus* and *Amorphognathus,* both of which may be lamellar conodonts (Rhodes, 1954); *Archeognathus,* discussed later in this paper; *Clavohamulus,* of very obscure affinities; *Lepodus,* which may well be a fish scale; and *Ptiloconus,* regarded by the original authors, Branson & Mehl, as probably a lamellar type conodont.

It should be emphasized here that the present report is limited in scope. Only two genera of the twelve listed above have been studied in detail. It appears that, in addition to the exceptions suggested above, the Neurodontiformes may be a heterogeneous group. Thus the description of "growth axes" in such genera as *Pteroconus* suggest that they may be lamellar forms. It is proposed to continue this investigation.

Stratigraphic, geographic and ecologic distribution.—The great majority of genera of the Neurodontiformes appear to be confined to the Middle Ordovician. If one includes *Amorphognathus* and *Ambolodus* within the group, however, it should be noted that these have been reported from Upper Ordovician strata. *Stereoconus* has been reported from the Lower Ordovician (Graves & Ellison, 1941), and the Upper Ordovician (Rhodes, 1953, p. 289). All the remaining genera (*Coleodus, Erismodus, Neocoleodus, Chirognathus, Leptochirognathus, Multioistodus, Cardiodella, Curtognathus, Polycaulodus, Mixoconus,* and *Trucherognathus*) are at present known only from the Middle Ordovician.

Virtually all known occurrences of the Neurodontiformes are in the United States (from Colorado to Minnesota and Missouri), although they have also been reported from South Wales (Rhodes, 1953) and from Sweden (Lindström, 1954). Their apparent absence in other areas almost certainly reflects the absence of any extensive microfaunal studies in rocks of comparable age.

The Neurodontiformes have been reported from various types of marine sandstones, siltstones, shales and limestones. They have been found associated with an equally varied fauna, including ostracoderms (Kirk, 1929), brachiopods, gastropods, cephalopods, *Receptaculites* (Amsden & Miller, 1942), scolecodonts (Stauffer, 1935), lamellar conodonts, trilobites, corals, sponges and crinoids (Rhodes, 1953).

The implication of these rather diverse occurrences and associations seems to be that the animals which bore the neurodontiform "teeth" inhabited a variety of marine environments. The absence of any apparent ecologic differences between faunas may further indicate the animals to have been pelagic, although the widespread distribution of many living benthonic species cannot be overlooked.

MICROSTRUCTURE

Methods.—Direct X-ray transmission patterns were made of oriented specimens mounted on scotch tape. Since these specimens are less than a millimeter in length, they were easily placed in the opening of a .010 pinhole, while the film was placed 3 cm. away from the specimen. Using filtered molybdenum radiation for 45 minutes at 40 kv. and 20 ma., satisfactory longitudinal and transverse patterns were obtained. An oriented longitudinal pattern was also obtained by using filtered copper radiation for 45 minutes at 40 kv. and 15 ma., so that the larger inner transmission circles could be used in giving more accurate information. These were studied for preferred orientation and computed to obtain chemical composition.

To determine whether any structure could be detected through direct radiation, microradiographs were made of six longitudinal sections, using filtered molybdenum radiation for 20 minutes at 40 kv. and 8 ma. The microradiographs were then enlarged 200×.

In addition to these X-ray studies, thin sections were cut and studied under high magnifications.

Results.—The results obtained from X-ray studies indicate a very pronounced preferred orientation in a direction parallel to the long axis of the specimens (Text-fig. 1–1). The pattern represented in this figure was obtained by recording X-ray diffraction perpendicular to the long axis of the specimen, *Stereoconus robustus*. The "fibrous" structure involving preferred orientation of crystallites is indicated by the intensity maxima on the diffraction rings in the figure. This is most conspicuous near the center, but is also present in the outer areas. In contrast to this pattern, a laminated structure or "cone-in-cone" type would give a uniform ring pattern, indicative of random orientation of crystallites. The presence of the ring concentrations represents the presence of local grouping of parallel reflecting planes. The curvature towards the left, which is visible in the inner rings, reflects the curvature of the long axis of the tooth, a fact which was confirmed by passing X-rays perpendicular to the long axis, through the basal one-third of the same specimen, the portion with the least curvature. The resultant photograph (Text-fig. 1–3) shows the ring concentrations to be directly opposite, indicating little or no curvature.

It is noteworthy that a presumed lamellar distacodid conodont, *Drepanodus altipies*, has been shown to exhibit "four positions of maximum darkening" (Rhodes, 1954, p. 430). This is an indication of its lamellar structure, and contrasts strongly with the structure of the present specimens.

In transverse section of the same specimen used for Text-fig. 1–1 and 1–3, a less conspicuous concentration may be observed (Text-fig. 1–2). This difference may represent a true grouping of crystals about the long axis, but it may, at least in part, be the result of interference of the long axis of the specimen, resulting from the curvature. To confirm the curvature interference the lower one-third was again X-rayed parallel to the long axis with the result that the interference due to curvature was almost eliminated (Text-fig. 1–4). The absence of any conspicuous grouping in this direction is therefore an indication that the elongation of the fibers is parallel only to the long axis of the specimen.

Microradiographic studies did not reveal any structure, which must therefore be very fine. They did reveal, however, the presence of what appears to be a closed basal cavity (Text-fig. 1–6 to 1–8) in specimens of the species *Stereoconus robustus*. This is particularly interesting in view of the fact that the genus is partly defined by the absence of an external basal cavity. When viewed from the basal surface there is no such trace of any cavity. It is proposed to further investigate this feature.

In thin section the fibrous structure is clearly visible only at a very high magnification (about 1000×). It is then seen to consist of a very large number of thin, irregular but elongated structures, which are variable in both their distribution and their form. They are strikingly different from the lamellar structure of the Conodontiformes, and suggest that the method of their formation may also be different from the latter. The structure is shown in thin section at low magnification in Text-fig. 1–5.

CHEMICAL COMPOSITION

Chemical compositional studies by X-ray methods provided the following data, the apparatus and exposures being the same as those used for textural studies:

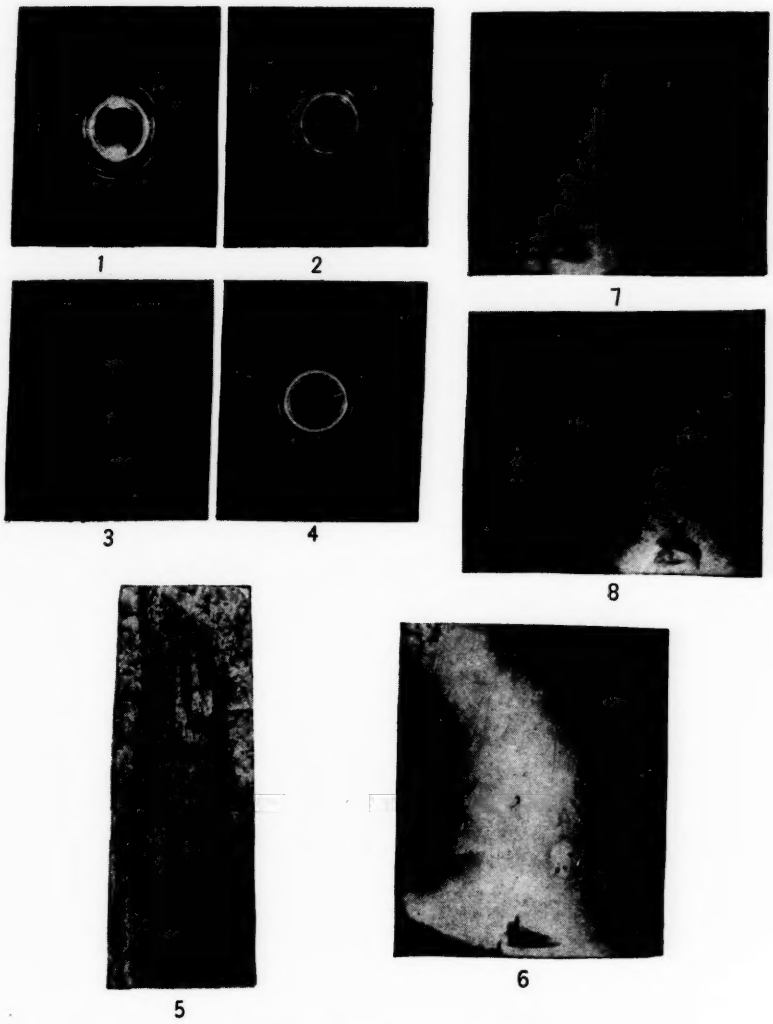
COPPER RADIATION

2S	*S*	*Tan 2θ*	*2θ*	*d-spacings*
2.5	1.25	.416	22°35′	3.95
2.8	1.40	.466	24°59′	3.56
3.7	1.85	.616	31°38′	2.83
4.0	2.00	.666	33°40′	2.66
5.0	2.50	.833	39°48′	2.26
7.0	3.50	1.166	49°23′	1.85

MOLYBDENUM RADIATION

2S	*S*	*Tan 2θ*	*2θ*	*d-spacings*
1.37	.685	.228	12°51′	3.18
1.55	.775	.258	14°28′	2.81
1.91	.955	.318	17°39′	2.30
2.50	1.250	.416	22°35′	1.81
3.15	1.575	.525	27°42′	1.48
3.95	1.975	.658	33°21′	1.24

The copper and molybdenum d-spacings were then combined and compared with the Hanawalt files.



TEXT-FIG. *1*—*Stereoconus robustus*

1,3, X-ray transmission patterns perpendicular to the long axis of the specimen showing a pronounced preferred orientation in a direction parallel to the long axis.

2,4, X-ray transmission patterns parallel to the long axis of the specimen. *2*, shows a ring concentration resulting from interference of the long axis of the specimen due to curvature. *4*, the lower $\frac{1}{3}$ of a specimen showing loss of ring concentration due to loss of specimen curvature.

5, Thin section of specimen in transmitted light showing fibrous structure at low magnification, ×300.

6–8, Microradiograph enlarged ×200 revealing the presence of what appears to be a closed basal cavity.

d-spacings found		*d-spacings in files* $Ca(PO_3)_2$	*Intensity*
		6.1	5
		5.6	5
		5.3	5
		4.45	6
3.95		4.0	6
3.56		3.55	100
		3.4	6
3.18		3.2	6
		3.0	6
2.83	2.81	2.83	60
2.66		2.5	15
		2.44	6
2.30	2.26	2.3	17
		2.02	20
		1.93	5
1.85		1.87	25
1.81		1.77	20
		1.69	4
		1.65	17
		1.58	20
		1.5	10
1.48		1.47	16
		1.41	4
		1.34	4
		1.32	4
		1.28	10
1.24		1.27	17
		1.21	6
		1.18	6

These transmission patterns indicate a chemical composition approximating calcium metaphosphate $Ca(PO_3)_2$.

The chemical composition of the Neurodontiformes is therefore broadly comparable to that of lamellar conodonts, the basal phosphatic material to which the latter are sometimes attached, and the armor of Paleozoic ostracoderms (Rhodes, 1954, p. 430). A number of recent workers have interpreted the presence of such a substance in the lamellar conodonts as indicative of their vertebrate affinities. It has already been remarked, however, that a number of invertebrates (e.g. polychaetes and inarticulate brachiopods) are capable of the external secretion of calcium phosphate, although there may well be a distinct physiological difference between its internal and external secretion. Comparable problems involved in the lamellar conodonts have been discussed by Rhodes (1954) and the arguments presented there are all applicable to the present discussion.

ZOOLOGIC AFFINITIES

The interpretation of the affinities of the Neurodontiformes presents a number of problems. There are, however, a number of groups with which they may be compared, and these will be discussed in turn.

Comparison of the Neurodontiformes and the Conodontiformes.—In spite of the fact that the Neurodontiformes are frequently referred to as "fibrous conodonts" they present a number of striking differences from the typical lamellar conodonts, the Conodontiformes of Branson & Mehl, 1944. These may be summarized as follows:

1) *External morphology.* Although there is a superficial resemblance between them, each of the two groups comprises a great majority of peculiar forms, which have no strictly comparable counterpart in the other group.

2) *Basal cavity.* The lamellar conodonts are characterized by a basal cavity which, though highly variable in form (Rhodes 1954, fig. 3), is a diagnostic feature of the group. The Neurodontiformes, however, generally lack such a cavity, although a number of genera develop an elongated groove on the aboral margin.

3) *Basal attachment.* Basal attachment of lamellar conodonts to phosphatic material is generally rare (Rhodes 1954, p. 426–430), while in fibrous forms it is very common.

4) *Stratigraphic range.* The lamellar conodonts are found from strata ranging from (Cambrian?) Ordovician to Triassic in age, whereas the fibrous forms are confined to the Ordovician. The majority of genera occur only in the Middle Ordovician, but there are a few records of Lower and Upper Ordovician occurrences (Müller, 1956).

5) *Microstructure.* The lamellar conodonts bear no resemblance to the microstructure and mode of growth displayed by the Neurodontiformes (Hass, 1941, Rhodes, 1954).

These differences are such that they suggest the possibility that the two groups of microfossils represent the remains of two entirely different groups of organisms. In view of this it appears preferable to restrict the term "conodont" to the lamellar forms and to discontinue its use for the Neurodontiformes. The lamellar forms' claim to retention of the term is justified by priority, by their relatively much greater abundauce than the Neurodontiformes, and by current practice and usage.

The basal attachment of neurodontiform teeth to phosphatic material was first noted by Kirk (1929) and has been commented upon by numbers of subsequent writers. The present study provides no new information on this subject, although it should be pointed out that the material does not ap-

pear to have the structure of bone, but appears rather to be dense and massive in structure.

Comparison of the Neurodontiformes with Archeognathus.—Apart from their general similarity to the Conodontiformes, from which they are structurally distinct, the Neurodontiformes present the closest similarity to the jaw-like structure *Archeognathus primus* (Text-fig. 2), originally described by Cullison from the Lower Ordovician of Missouri (Miller, Cullison & Youngquist, 1947). A study of the holotype of this curious species confirms this broad

TEXT-FIG. 2—*Archeognathus primus*. Photograph of holotype. Enlarged ×8.7.

similarity, although the basal attachment of the denticles in *Archeognathus* appears unlike anything so far reported from the Neurodontiformes. X-ray studies of the specimen could not be made as the specimen is embedded in plastic. A second apparent difference between *Archeognathus* and the Neurodontiformes, lies in the fact that the denticles of the former appear to form a continuous fused series. The few which are separated from their neighbors appear to have been fractured at their base.

On such slender evidence it is difficult to be sure of the relationship between the Neurodontiformes and *Archeognathus*. They certainly show broad similarities but they also display apparent differences.

Comparison of the Neurodontiformes with some invertebrates.—Structures bearing some resemblance to the Neurodontiformes are found in gastropod radulae, in the "jaws" of polychaetes and on the carapaces of some arthropods. From all such organs, however, the Neurodontiformes differ in having a phosphatic, rather than a chitinous, composition. Furthermore the basal attachment of very many specimens to massive phosphatic material is quite unrepresentative of these invertebrate groups. These distinctive features would appear to exclude the Neurodontiformes from these phyla.

Possible affinities of the Neurodontiformes.—The chemical composition, the basal attachment, and the apparent pelagic habit of the neurodontiform-bearing animals suggest that they probably represent a group of extinct, and otherwise unknown, vertebrates. It seems impossible to regard them as Agnatha, and in fact the only valid comparison seems to be with *Archeognathus*, to which they appear closely related and to which they may be identical.

The affinities of *Archeognathus* are also obscure. Its general structure strongly suggests that of a premaxilla, a membrane bone that is first recognized in the Osteichthyes, but is unrepresented in the lower classes of Pisces. Schaeffer & Gregory (in Miller, Cullison & Youngquist, 1947, p. 32) considered that whereas it "may very well be a Lower Ordovician vertebrate jaw element, its definite identification as a premaxillary might be open to question." It appears, however, to be difficult to regard it as anything other than a primitive craniate.

If the vertebrate origin of the Neurodontiformes and of *Archeognathus* is accepted, the present concepts of the phylogeny of the Pisces stand in need of modification. Some of the Neurodontiformes as well as *Archeognathus* are geologically older than the oldest known Agnatha from the Harding sandstone of Colorado, the Bighorn formation of Wyoming, and the Whitewood dolomite of South Dakota (Miller, Cullison and Youngquist, 1947). It cannot yet be demonstrated, however that these "Agnatha" do not also represent the remains of the vertebrates which bore the Neurodontiform teeth.

SUMMARY AND CONCLUSIONS

The Neurodontiformes are a group of minute tooth-like fossils which appear to

be confined to the Ordovician. They are somewhat variable in form but may be divided into three broad morphological groups. Some included genera are such as to suggest that the group may be heterogeneous. These microfossils are known from both Europe and North America and occur in a variety of neritic sediments. X-ray diffraction and microradiograph photographs and thin section studies indicate that they have a minute "fibrous" structure, and the composition of calcium metaphosphate, $Ca(PO_3)_2$. It is suggested that they are distinct from the conodonts and also other invertebrate groups, to which they bear some resemblance. They appear to be related, and perhaps identical, to *Archeognathus*, a Lower Ordovician probable vertebrate.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 2, P. 455–464, 6 TEXT-FIG., MARCH 1957

PALEONTOLOGICAL NOTES

STILLINA, A NEW GENUS OF CRETACEOUS OSTRACODA

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An examination of samples from a number of well-known Lower Cretaceous fossil localities resulted in the discovery of the very distinctive little ostracode described in this report. Despite its small size, it is very easily recognized, and should prove useful. It was found in the following samples from Texas and Arkansas:

Sample *a:* Goodland formation, Comanche series of the Lower Cretaceous (Albian) of Texas. Sample collected by Mr. J. W. West in 1952, in Tarrant County, Texas, at the locality described as Station 1 by C. I. Alexander, Tex. Univ. Bull. 1929. "An excellent outcrop of the Goodland formation occurs at the Lake Worth dam. Below the dam, black basal shales of the Goodland lie on the uppermost ledges of the Walnut shell agglomerate." *Stillina asterata* is represented in the sample from this locality by two right and two left valves. The specimens are well preserved.

Sample *b:* Goodland formation, Comanche series of the Lower Cretaceous (Albian) of Texas. Sample collected by Dr. H. V. Howe in 1952, in Tarrant County, Texas. The collection was made at the locality described as Station 3 by C. I. Alexander in Tex. Univ. Bull. 1929: "An excellent exposure of upper Goodland occurs in a low bluff on the east bank of North Fork of Mary's Creek, at the concrete bridge on the Fort Worth-Weatherford road about 11½ miles west of Fort Worth." The new genus is present in this sample with five right valves and a left one. The specimens are not well preserved.

Sample *c:* Kiamichi form. Comanche series of the Lower Cretaceous (Albian) of Texas. Sample collected by Mr. J. W. West in 1952, in Tarrant County, Texas. The collection was made from the lower shales at Alexander's locality, Station 5, which is described in Tex. Univ. Bull. 1929: "The entire Kiamichi formation is exposed in the deep road cut on the 'Stove Foundry Road', just north of the new Texas Pacific Railroad shops, Forth Worth. At this locality the formation grades from black shales at the bottom of the exposure to yellow clays at the top." *Stillina asterata* is well represented in this sample by five right and thirteen left well preserved valves.

Sample *d:* Formation mapped as Upper Trinity, Comanche series of the Lower Cretaceous (Albian) of Arkansas. The sample was collected by Prof. B. C. Craft, in 1939 in SW¼ sec. 23, T. 8 S., R. 28 W.; Howard Co., Arkansas (for map of the locality see: Guidebook, Shreveport Geol. Soc. 14th Ann. Field trip, 1939, p. 199–200, stop 1). *Stillina asterata* is here represented by three left valves. The specimens are well preserved.

The writer wishes to express her thanks to Dr. H. V. Howe, at whose suggestion this work was undertaken and whose assistance has been invaluable. The author also thanks Mr. J. W. West and Prof. B. C. Craft who collected the material for this study.

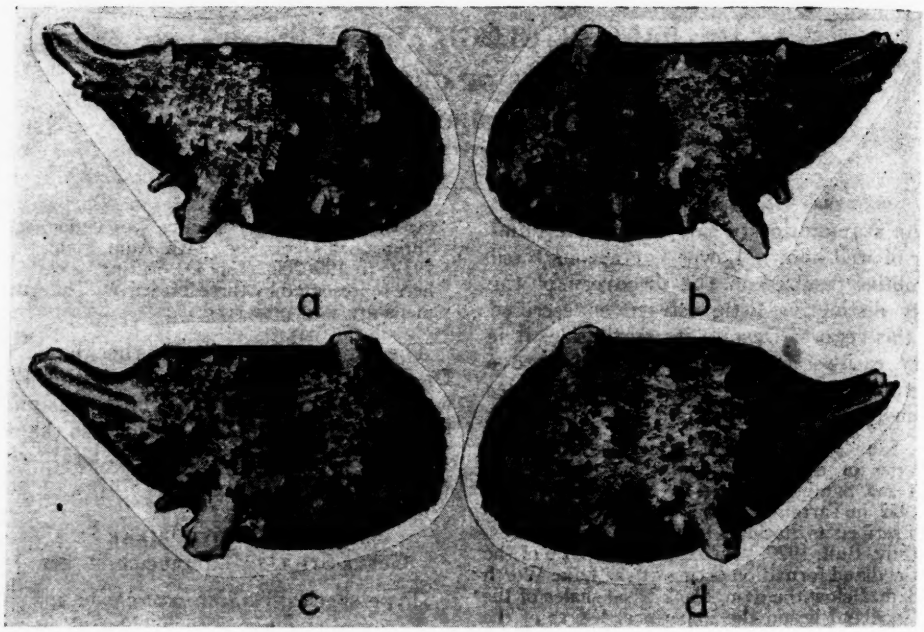
Subfamily CYTHERURINAE Sars

Genus STILLINA Laurencich, n. gen.

Type species: *Stillina asterata* n. sp.

External shape guttiform. Dorsal margin straight, anterior margin obliquely rounded, ventral margin rounded. The posterior area bears an upturned caudal process which is situated near the posterior cardinal angle. Carapace convex, more tumid ventrally, divided into two subequal lobes by a faint vertical depression which is situated near the median vertical line of the carapace. Eye tubercles prominent. A characteristic long, strong laterally projecting spine is near the ventral margin, slightly behind the middle. In addition to this prominent spine, the surface bears other shorter, variously scattered spines and is usually pitted. Hingement holomerodont: it consists, in the right valve, of a crenulate bar with two terminal notched cusps; in the left valve of a crenulate groove with two terminal grooved furrows. Marginal area relatively narrow; no vestibule. Radial canals widely spaced, few, short and delicate. Muscle scars indistinct.

Remarks.—This genus resembles in its general external characters the genus *Paijenborchella* Kingma (1948, p. 85) but it differs in having a holomerodont hingement instead of a schizodont one; in the pore canals which are short and simple instead of long and bifurcate in the caudal region. The genus *Stillina* can be compared also to the



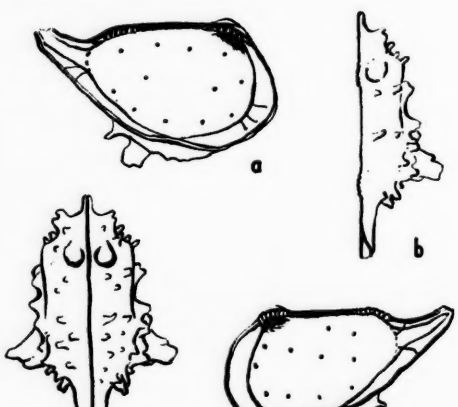
TEXT-FIG. *1*—*Stillina asterata*, n. sp.

a, Holotype slide No. 4142, exterior right valve of a male. Locality *c*.
b, Holotype slide No. 4142, exterior left valve of a male. Locality *c*.
c, Paratype slide No. 4143, exterior right valve of a female. Locality *c*.
d, Paratype slide No. 4143, exterior left valve of a female. Locality *c*.

genus *Orthonotacythere* Alexander (1933, p. 199) which it resembles in the characters of the radial pore canals and the general ornamentation; but from which it differs in bearing a holomerodont hingement instead of an antimerodont one in having a more delicate and elegant shape, and in the caudal process which, in *Stillina*, is much longer and twisted in the terminal portion.

STILLINA ASTERATA Laurencich, n. sp.

Carapace tumid, guttiform, in side view. Dorsal margin straight; anterior margin obliquely rounded and, in well preserved specimens, dentate; ventral margin arcuate to the tip of the caudal process. The caudal process which is situated near the posterior cardinal angle is long, narrow, upturned and in the terminal portion is slightly twisted to the right in the right valve and to the left in the left one. Viewed dorsally the contact margin is straight to the terminal portion of the caudal process where the two dorsal borders are slightly disjoined. Surface coarsely pitted and bearing spines, one of



TEXT-FIG. *2*—*Stillina asterata*, n.sp.

a, Paratype slide No. 4143, interior view of left valve. Locality *c*.
b, Paratype slide No. 4143, dorsal view of right valve. Locality *c*.
c, Paratype slide No. 4143, dorsal view of the complete carapace.
d, Paratype slide No. 4143, interior view of right valve. Locality *c*.

which is much more elongated and strong and projects backward-laterally in an alaeform manner. Eye tubercles very prominent. A slight depression extends from the center of the dorsal margin toward the venter. Viewed from the inside, the valves are deep especially in the ventral region. On the internal surface they show numerous holes, each one corresponding to an external spine. Hingement holomerodont, characteristic of the genus. Muscle scars indistinct. Radial pore canals short and delicate; only two or three have been seen in the anterior region and in the posterior. Sexual dimorphism weak; the female is a little higher and the anterior-ventral area is more inflated than in the male.

Dimensions.—Greatest height anterior to center if one excludes the alaeform spine. Greatest length between the extreme point of the caudal process and somewhere below the middle of the anterior margin. Greatest thickness immediately above the alaeform spine.

Measurement in millimeters of the figured specimens:
Holotype, right valve of a male (Text-fig. 1a), length, 0.61; height 0.30.
Holotype, left valve of a male (Text-fig. 1b), ength, 0.60; height 0.30.
Paratype, right valve of a female (Text-fig. 1c), length 0.60; height 0.31.
Paratype, left valve of a female (Text-fig. 1d), length 0.60; height 0.32.
Complete specimen (Text-fig. 2), thickness through the body, 0.30.
Complete specimen (Text-fig. 2), thickness from spine to spine, 0.43.

Repository.—Holotype, no. 4142, and paratype, no. 4143, both from sample *c* are deposited in the Howe's Collection, Louisiana State University, Baton Rouge, Louisiana. A topotype is deposited in the United States National Museum, Washington.

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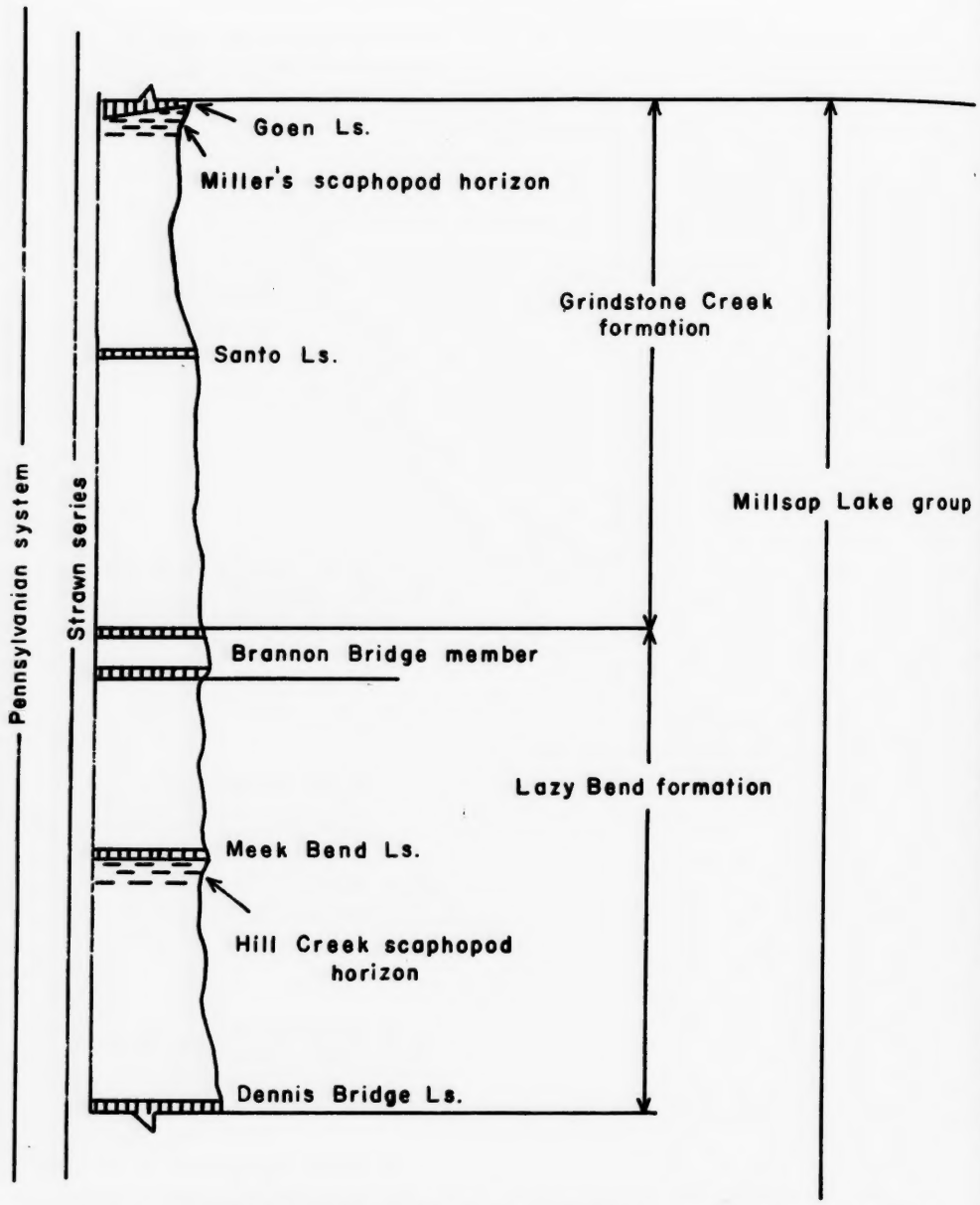
GIANT SCAPHOPOD FRAGMENT FROM THE LOWER STRAWN (PENNSYLVANIAN) OF NORTH-CENTRAL TEXAS*

DONALD F. TOOMEY
Shell Development Company, Houston

The scaphopoda have received comparatively little attention by paleontologists, although locally, as in some late Paleozoic marine sediments, they are quite abundant. They are perhaps overlooked as not being a readily apparent part of the fauna, because they generally are associated with a richer and varied assemblage of more obvious forms that are sought after by the collector, and hence scaphopods go unreported. There is a dearth of literature dealing with Paleozoic scaphopods although Shrock & Twenhofel (1953, p. 363) report that more than 300 fossil species, mostly Tertiary forms, have been described in the literature.

The giant scaphopod fragment under consideration was found May, 1956, in the Hill Creek beds of Lower Strawn age in southwestern Parker County, Texas, by D. L. Amsbury, who kindly loaned it to the author for study and description. In addition the author and D. L. Amsbury obtained a fairly complete faunal collection from the scaphopod horizon.

* Publication No. 107, Shell Development Company, Exploration and Production Research Division, Houston, Texas.

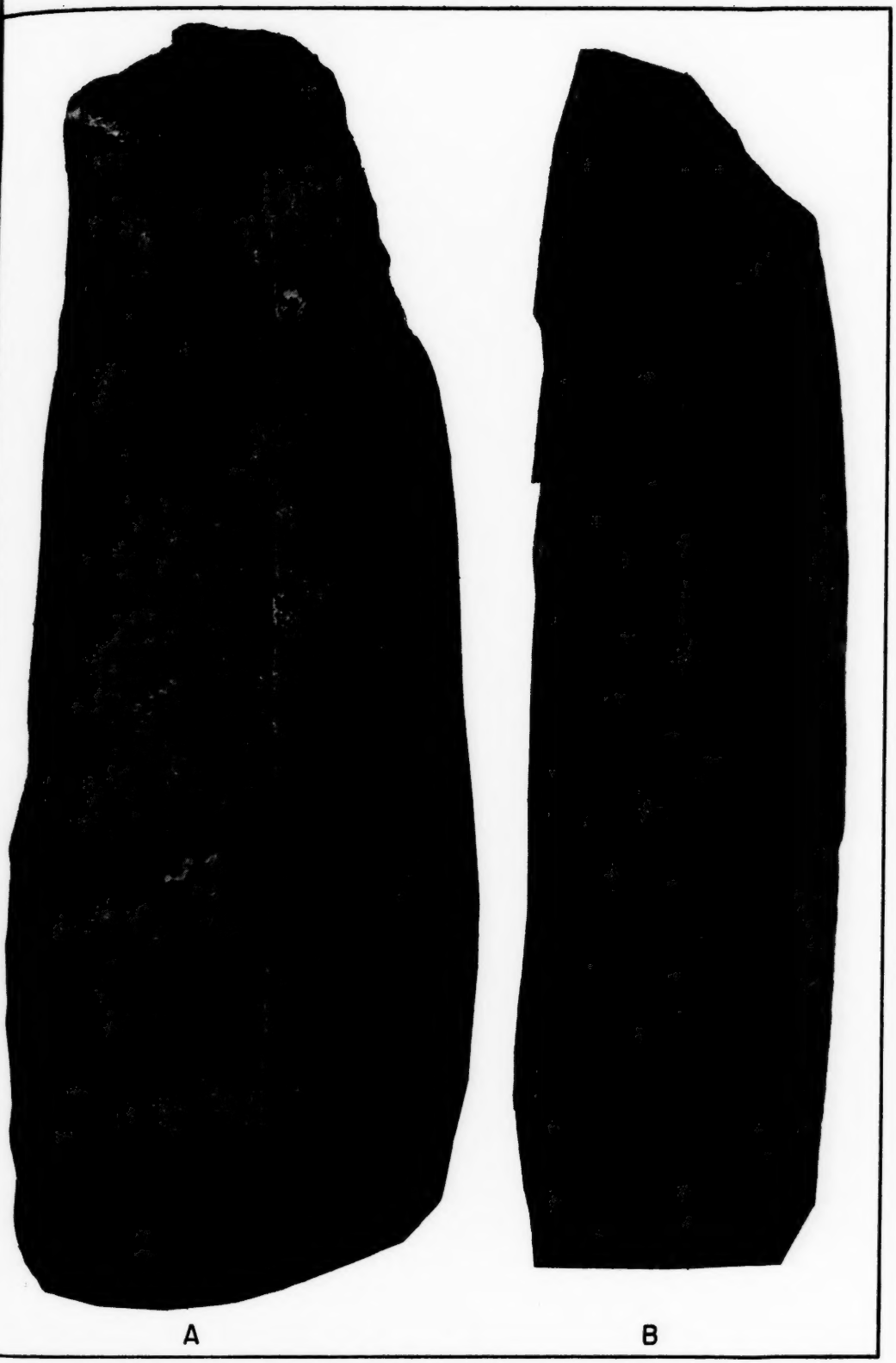


TEXT-FIG. *1*—Generalized geologic section, modified from Hendricks, Vertical scale: 1″ = 200′.

DENTALIUM (ANTALIS) RAYMONDI (Young)
Text-fig. 2

?Dentalium sp. GIRTY, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 251, 261, 452.
Prodentalium raymondi YOUNG, 1942, Jour. Paleont., vol. 16, p. 120–121, pl. 20, fig. 3–6,8, 12.
Dentalium (Antalis) raymondi MILLER, 1949, Jour. Paleont., vol. 23, p. 387–391, pl. 76, fig. 1–4.

The specimen studied is a fairly well preserved fragment not showing any effects of distortion or crushing. However, the



TEXT-FIG. 2—*Dentalium* (*Antalis*) *raymond:* (Young), ×1. View of complete fragment showing numerous transverse convex growth lines and longitudinal section showing thick shell wall; from the Lower Strawn Lazy Bend formation in southwestern Parker County, Texas.

surface of the specimen has been exposed to weathering and much of the shell ornamentation has been obliterated. The over-all length of the preserved portion measures 184 mm; posterior apertural diameter approximately 40 mm, and anterior apertural diameter approximately 60 mm. The maximum thickness of the shell is 7 mm, and is composed of numerous thin concentric layers. The exterior of the test is marked by abundant transverse, convex, growth lines.

Associated with the scaphopods at the Hill Creek horizon was a dominantly molluscan fauna consisting of the following:

Pelecypoda:
Myalina sp. [fragments]
Gastropoda:
Bellerophon cf. *crassus* Meek & Worthen
Straparolus (*Amphiscapha*) sp.
Goniasma lasallensis (Worthen)
Soleniscus? sp.
Anomphalus cf. *umbilicatus* Knight
Pseudozygopleura sp.
Cephalopoda:
Pseudorthoceras knoxense (McChesney)
Polychaeta:
Spirorbis sp. cf. *S. carbonarius* Dawson
[Encrusting on shells of *Dentalium* sp. and *Bellerophon* cf. *crassus* Meek & Worthen.]

It is of interest to note that many of the *Dentalium* shells were encrusted by polychaete worm tubes of the genus *Spirorbis*. Most of the scaphopod fragments had worm encrustations on either the ventral or dorsal sides of the shell; a few on both sides. This seemingly indicates a moderate amount of rolling of the shell, caused by wave currents, after death of the animal. The association of a dominantly molluscan fauna suggests a soft, muddy bottom environment compatible to molluscan growth.

Remarks.—The above specimen is similar to the *Dentalium* fragments described by Girty (1903, p. 451–452) from the Cisco division near the town of Graham, Young County, Texas. His fragment measured 200 mm. in length, a diameter of upwards of 30 mm., and a shell thickness of from 4 to 5 mm. Unfortunately the specimen was never figured.

Miller (1949, p. 387–391, pl. 76) described and illustrated an unusually well preserved, essentially complete, giant scaphopod from Strawn beds in Palo Pinto County, Texas, that are stratigraphically younger than the Hill Creek horizon. Miller's specimen measured 252 mm. in length; it had a posterior width of 10 mm., and a maximum width of 35 mm. Miller referred his specimen as being conspecific to the fragments described from the Pennsylvanian of New Mexico by Young (1942, p. 120–121, pl. 20, fig. 3–6, 8,12), which attained a length of 125 mm. and a maximum diameter of 29 mm.

The most significant characters of the giant scaphopod fragment from the Hill Creek beds is the great length of the test, and the extremely large diameter of the apertural opening, which if expanded and tapered gradually would undoubtedly have attained a length of well over 300 mm. To the writer's knowledge this marks the lowest stratigraphic horizon in which giant scaphopods have been reported from the Pennsylvanian of North America.

Occurrence.—The giant scaphopod fragment came from the uppermost shales of the Hill Creek member of the Lazy Bend formation of Strawn age in southwestern Parker County, Texas. The exposure may be reached by traveling southwest on U. S. Highway 80 from Weatherford to Strawn; approximately 1.1 miles from the Brazos River turn south on a ranch road and travel southwest 7.3 miles to the Hill Creek locality. Exposures to the northwest consist of low rounded hills of Hill Creek shale capped by remnants of Meek Bend limestone.

Repository.—The University of Texas Pennsylvanian collection, UT-12039.

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NEW TECHNIQUE FOR CASTING FOSSILS AND FORMING MOLDS

ROBERT O. VERNON
Florida Geological Survey, Tallahassee

Molds and impressions are among the more difficult fossil-preservations to study adequately. Invertebrates, in general, and mollusks, in particular, are poorly preserved in a carbonate section such as that of Florida. In most cases, an impression of the skeleton is all that is left of the original organism. These molds are generally well preserved, but the loosely cemented, granular limestone and dolomite often make it difficult to chip them out of the rock.

Several days are required to obtain a representative collection of the fauna using wax or latex rubber impressions. With wax the impressions are generally poor, difficult to obtain, photograph badly, and deform easily, thus making them useless for types. Latex requires application in thin layers with intervals to dry; where the impression is in a quarry wall, retaining dams are commonly required. There is a real need of some type of casting material that can be formed cold or under low heat. The material should be plastic and fluid enough to penetrate hair-like pores, veins and pits to give exact definitions of the mold. Some means of handling the material with the fingers is desirable and once inserted into a mold the material should set rapidly so that casts can be taken from exposures in vertical quarry walls, without the use of retaining dams. The setting time on the material should be within the range of five minutes. Simplicity in the mixing of ingredients, if separate substances are required, is very desirable since it is impractical to take a number of containers, a delicate balance and mixing equipment into the field. The best substance would be a prepared mix to which water or some solvent could be added or one that would require a low heat. The resistance to acids and alkalies is not a requirement for fossil casting, but the cast must be rigid or must retain its shape, if elastic, and should not deform under normal temperatures and pressures. Such specifications would appear almost impossible to meet, but we have recently obtained from the Calresin Corporation, 4543 Brazil Street, Los Angeles 39, California, a casting material known as "Green Mold Plastiflex" that meets all requirements.

Plastiflex is a highly plasticized type of polyvinyl chloride of the hot melt variety. It is 100 per cent reclaimable; discarded, preliminary, and out-dated molds can be remelted and reused. The manufacturers recommend that the plastic be heated in an oil bath as the temperature must be kept within narrow ranges or Plastiflex will discolor under too intense heat. The plastic is most fluid at 340° to 360° Fahrenheit. We have had success in using "canned heat" in the field and an electric hot plate, equipped with a variable rheostat in the laboratory. The heat can be applied directly beneath a large porcelain dish provided the plastic is stirred while in use.

One characteristic worthy of note by those who have been forced to work with some of the vile-smelling casting compounds is that Plastiflex has a very pleasant piquant odor. The plastic when heated is very fluid and can be applied directly to the mold without previous treatment of the mold. It hardens instantaneously, upon cooling.

TEXT-FIG. *1*—Cast of mold taken from the Crystal River formation, Eocene age.

The cast is elastic and retains the finest lines of the impression.

Plastiflex has been used during the past year by the Florida Survey and we have made hundreds of casts of mollusks from the molds of the Ocala limestone. These are easy to work with, the material being inert and a hard, elastic plastic with a pleasant dark green color. The color and form of these molds photograph effectively (Text-fig. 1).

To take casts of molds in rock, the following simple technique is employed:

> Heat (use canned heat in the field) in a porcelain dish until Plastiflex melts. Heat evenly to avoid burning and stir occasionally with a glass rod to a consistent fluid paste. Pour into mold, if it is possible to do so, or take a solid piece of the Plastiflex of appropriate size to fill the mold, immerse the solid into the melt until coated and press into the mold. Pull out the cast.

The Survey has also been successful in using Plastiflex for forming molds of vertebrate fossils. The details of casts taken from these molds equal or exceed the definition obtained from other molding compounds, and the time required to prepare the mold is reduced from hours to minutes. Because of the heat involved, caution must be taken to insure that the specimen to be cast is not cemented nor built up of materials such as wax, that will deteriorate under heat.

The use of Plastiflex opens the possibility of obtaining casts of type vertebrate speci-

TEXT-FIG. *2*—Mold of Plastiflex in "mother" mold of plaster of Paris.

mens in short time periods that will not involve large areas of space for mold preparation and will allow the original specimen to be cast and returned immediately to storage or display. The plastic has been used for specimens as large as the jaw of the large Miocene dogs, where fine details were required. Molds of teeth of the sabre-toothed tiger have been prepared as fast as one per minute.

Large specimens can be easily handled over an electric roaster equipped with removable containers and a thermostat control. The roaster will hold from 30 to 35 pounds of Plastiflex. A temperature of 350° Fahrenheit is best; the plastic deteriorates above this temperature. The plastic should not be kept melted longer than necessary, but if continuous casting or molding is being done and new material is being added periodically, continuous melts are permissible.

Large porous bones contain air that may cause bubbles in the plastic, but if the Plastiflex is troweled or brushed on to make an initial thin coating, all of the details can be reproduced without this difficulty. Bubbling can also be overcome by preheating the bone to about 200 degrees Fahrenheit before placing it into the melted Plastiflex. Plastiflex replaces the latex rubber commonly used in other molding methods, but molds and casts of plaster of Paris must be prepared in the usual way. Supporting or "mother" molds of clay or plaster are required for casting of large specimens (Text-fig. 2).

Those interested in further details may correspond with the Florida Geological Survey or the Calresin Corporation. The prevailing prices for Plastiflex Standard Mold Material range from 80 cents to $1.10 per pound, depending upon the quantity.

MARINE ECOLOGY AS AN AID IN TEACHING INVERTEBRATE PALEONTOLOGY

WILLIAM H. MATTHEWS III
Lamar State College of Technology, Beaumont, Texas

With the growth of paleoecology as an acessory exploratory technique of the petroleum geologist, the writer has attempted to introduce to his invertebrate paleontology classes some of the basic concepts of marine ecology. The encouraging results and the enthusiasm of the students prompted the writing of this paper.

Many excellent references are available for reading assignments and current textbooks have sections dealing with the ecology of all major taxonomic groups. The study of members of the various phyla from a zoological viewpoint and in their natural habitats emphasizes the importance of a biological background for the working paleontologist.

Colleges and universities in coastal areas are favorably situated for investigations of this nature; however, institutions located a reasonable distance inland should find a longer trip well worth the time involved. Trips could be made in conjunction with invertebrate zoology or field ecology classes.

A marine-ecology trip is conducted at Lamar Tech in one day because of proximity to the Gulf of Mexico. Several days prior to the trip an outline covering the following points is issued to the students:

1) *General area of investigation.* The area in which the trip is to be conducted is briefly described. Geographical coordinates, type of coast line, range of tides, prevailing winds, type of bottom, depth, salinity and temperature of the water are some of the items covered.

2) *Specific stations to be studied.* Stations are designated on the map and a brief description of each locality and the type of fauna to be encountered are noted. A typical description follows:

Station I—Sydnors Bayou (See Map No. I), a partially closed body of water with a brackish water fauna. The bayou is surrounded by a small salt marsh, and pilings extend out into the water affording attachment for many sessile organisms. The salt marsh and mud flat exposed during low tide will be studied in some detail.

Several methods of study are used to obtain representative samples of the population at each station:

Population sample counts. Approximately one square foot of substratum is outlined by means of a wooden frame and the surface is counted. The area may be spaded up, screened and washed and the remaining animals counted.

Collection of specimens. May be accomplished in several ways:

1) *Screening.* Burrowing clams, annelids, etc. may be taken by washing bottom material through a 36×24 inch screening frame.
2) *Spading.* Certain mollusks and arthropods may be taken by digging near the opening of their burrows.
3) *Dip-net.* Two nets are used, a large net with a one-half inch mesh of heavy netting is used for crabs and larger forms. A butterfly net is used to catch smaller organisms.
4) *Plankton catch.* A plankton net is used to collect a representative sample of plankton and these forms are studied later under the microscope.
5) *Beach collecting.* Certain animals may be left stranded by the tides and others are blown in from the Gulf and deposited on the beach.
6) *Near-shore dredging.* A small dredge towed offshore will recover many neritic benthonic forms.

Salinity determination. Hydrometers and Knudsen's tables are used to obtain salinity readings at each station.

Temperature readings. Both air and water temperatures should be taken at each station.

On Galveston Island, Texas, the following habitats may be conveniently studied:

Rocky shore. At Galveston the rocky shore is a man-made environment resulting from the construction of a pair of stone jetties. Wave action, scour, and salinity variations are important in this environment.

Sandy beach. The beaches support relatively few organisms, but burrowing pelecypods, and gastropods are found along the strand. Many dead shells of animals inhabiting the near-shore bottom may also be collected on the beaches. These specimens are useful as comparative material in the laboratory.

Mud flat and brackish water. Forms typical of this hibitat may be studied with respect to environmental adaptation.

Near-shore bottom. Inhabitants of this environment are best collected by means of a small dredge. The plankton net may also be towed during this operation.

The above habitats support interesting faunas representing different sedimentary and biological environments.

Studies of this type acquaint the student with the paleoecological approach in the solution of paleontological and stratigraphic problems. The student is introduced to:

1) A variety of ecological situations.
2) Types of organisms inhabiting the environments and their relationship to each other. Predators, scavengers, commensals, parasites, and others are pointed out.
3) Effect of these organisms on the sedimentary environment.
4) Structural variations of organisms as a result of adaptation to such modes of life as burrowing, swimming, and attachment.
5) Examples of faunal zonation and factors controlling zonation.
6) The use of recent material in illustrating similarity among taxonomic groups and a comparison between recent and fossil forms.
7) Methods by which fossil assemblages might be classified as biocoenoses or thanatocoenoses.
8) A systematic method of investigating the ecology of a given area.
9) A correlation between neontological and paleontological techniques.

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JOURNAL OF PALEONTOLOGY, VOL. 31, NO. 2, P. 465–466, MARCH, 1957

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

PROGRAM FOR S.E.P.M., ST. LOUIS MEETING (Kiel Auditorium)

Richard V. Hollingsworth, Technical Program Chairman

TUESDAY, APRIL 2 — 1:30 P.M.

Assembly Hall No. 1, Kiel Auditorium

RESEARCH COMMITTEE SYMPOSIUM: BIOSTRATIGRAPHY

1. INTRODUCTION, Curt Teichert, U. S. Geological Survey, Denver, Colorado, and Alfred A. Loeblich, Jr., U. S. National Museum, Washington, D. C.
2. PRIMARY FACTORS IN BIOSTRATIGRAPHY, V. Standish Mallory and Harry E. Wheeler, University of Washington, Seattle, Washington
3. CAMBRIAN BIOSTRATIGRAPHY IN NORTH AMERICA, Christina Lochman-Balk, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, and James Lee Wilson, Shell Development Company, Houston, Texas
4. THE SILURIAN-DEVONIAN BOUNDARY IN THE ARBUCKLE REGION, OKLAHOMA, Thomas W. Amsden, Oklahoma Geological Survey, Norman, Oklahoma.
5. EVOLUTION AND STRATIGRAPHIC USE OF BRYOZOANS, M. K. Elias, Nebraska Geological Survey, Lincoln, Nebraska
6. STRATIGRAPHIC DISTRIBUTION OF SOME UPPER PENNSYLVANIAN FUSULINIDS FROM CENTRAL TEXAS, Donald A. Myers, U. S. Geological Survey, Denver, Colorado
7. PLANT MICROFOSSILS IN THE CABANISS COALS OF OKLAHOMA AND KANSAS, L. R. Wilson, New York University, New York, New York, and William S. Hoffmeister, Carter Oil Company, Tulsa, Oklahoma
8. CORRELATION OF THE GULF AND ATLANTIC COASTAL PLAIN PALEOCENE-LOWER EOCENE BY MEANS OF PLANKTONIC FORAMINIFERA, Alfred R. Loeblich, Jr., and Helen Tappan Loeblich, U. S. National Museum, Washington, D. C.

WEDNESDAY, APRIL 3 — 9:00 A.M.

Assembly Hall No. 1, Kiel Auditorium

SEDIMENTARY MINERALOGY, PETROLOGY, AND SEDIMENTOLOGY

1. SURF-STRENGTH FACTORS IN REEF GROWTH AND DEVELOPMENT, Robert J. Burnside, U. S. Geological Survey, Denver, Colorado
2. ORIGIN OF BAHAMIAN OOLITE, Norman D. Newell, Edward G. Purdy, and David L. Thurber, Columbia University, New York, New York
3. BEACH SANDS FROM THE NORTHERN MARSHALL ISLANDS, Dorothy Carroll, U. S. Geological Survey, Washington, D. C.
4. CALCIUM CARBONATE DEPOSITION WEST OF ANDROS ISLAND BAHAMAS, Preston E. Cloud, Jr., Paul D. Blackmon, and Frederick D. Sisler, U. S. Geological Survey, Washington D. C.
5. PALEOECOLOGY OF THE NODULOSE ZONE AT THE TOP OF THE HASKELL LIMESTONE (UPPER PENNSYLVANIAN) IN KANSAS, Halsey W. Miller and Ada Swineford, Kansas Geological Survey, Lawrence, Kansas
6. PRACTICAL PETROGRAPHIC CLASSIFICATION OF LIMESTONES, Robert L. Folk, University of Texas, Austin, Texas

WEDNESDAY, APRIL 3 — 2:00 P.M.

Assembly Hall No. 1, Kiel Auditorium

SYMPOSIUM ON GEOCHEMISTRY OF SEDIMENTARY MATERIALS

1. INTRODUCTION, W. J. Plumley, California Research Corporation, La Habra, California
2. CERTAIN ASPECTS OF THE THERMOCHEMISTRY OF CHEMICAL SEDIMENTATION, Gordon J. F. MacDonald, U. S. Geological Survey, Denver, Colorado
3. THE OCCURRENCE OF ALKALI METALS IN SOME GULF OF MEXICO SEDIMENTS, Charles W. Welby, Middlebury College, Middlebury, Vermont
4. BIOGEOCHEMISTRY OF CALCIUM CARBONATE PRECIPITATED BY MARINE ORGANISMS, Heinz A. Lowenstam, California Institute of Technology, Pasadena, California

5. CHEMICAL FACIES IN THE FLORENA SHALE (PERMIAN) OF NEBRASKA, KANSAS, AND OKLAHOMA, John Imbrie, Columbia University, New York, New York
6. SOME VIEWS AND EXPERIMENTS ON THE CRYSTALLIZATION OF DOLOMITE, Julian R. Goldsmith, University of Chicago, Chicago, Illinois
7. THORIUM TO URANIUM RATIOS AS INDICATORS OF SEDIMENTARY PROCESS, THE CONCEPT OF GEOCHEMICAL FACIES, John A. S. Adams, The Rice Institute, Houston, Texas and, Charles E. Weaver, Shell Oil Company, Houston, Texas

THURSDAY, APRIL 4 9:00 A.M.

Assembly Hall No. 1, Kiel Auditorium

PALEONTOLOGY AND STRATIGRAPHY

1. BITHECAE AND NEMATOTHECAE ON SPECIES OF GRAPTOLOIDEA, Charles E. Decker, University of Oklahoma, Norman, Oklahoma
2. MIOGYPSINIDS, PLANKTONIC FORAMINIFERA, AND GULF COAST OLIGOCENE-MIOCENE CORRELATIONS, W. H. Akers, The California Company, New Orleans, Louisiand, and C. W. Drooger, Geologische Institut, Universiteit Utrecht, Utrecht, Netherlands
3. METHODS OF CORRELATION IN SOUTHERN CALIFORNIA, W. T. Rothwell, Richfield Oil Corporation, Long Beach, California
4. THE RELATION BETWEEN CHAROPHYTE EVOLUTION AND STRATIGRAPHIC CORRELATION IN THE MORRISON FORMATION, Charles A. Ross, Yale University, New Haven, Connecticut
5. CONODONTS FROM THE GLEN DEAN FORMATION IN ILLINOIS, INDIANA, AND WESTERN KENTUCKY, Carl B. Rexroad, Texas Technological College, Lubbock, Texas
6. PALYNOLOGY OF RECENT ORINOCO DELTA AND SHELF SEDIMENTS, J. Miller, Compania Shell de Venezuela, Maracaibo, Venezuela
7. DISPLACEMENT OF MICROFOSSILS—A REVIEW, Daniel J. Jones, University of Utah, Salt Lake City, Utah

THURSDAY, APRIL 4 2:00 P.M.

Assembly Hall No. 1, Kiel Auditorium

SEDIMENTARY MINERALOGY, PETROLOGY, AND SEDIMENTOLOGY

1. CARBONATE REPLACEMENT OF QUARTZ AND FELDSPAR AS A SOURCE OF SILICA IN CHERTIFIED SEDIMENTS, Theodore R. Walker, University of Colorado, Boulder, Colorado
2. USE OF THE CURVED-CRYSTAL SPECTROMETER FOR MINERALOGICAL INVESTIGATIONS, I. Adler and J. M. Axelrod, U. S. Geological Survey, Washington, D. C.
3. AGE DETERMINATIONS ON ZIRCON, A POSSIBLE AID IN PROVENANCE STUDIES, Howard W. Jaffe, David Gottfried, and Claude L. Waring, U. S. Geological Survey, Washington, D. C.
4. PETROLOGY OF THE CRETACEOUS WOODBINE SAND IN NORTHEAST TEXAS, August S. Cotera, Jr., Liberal, Kansas
5. STRATIGRAPHIC AND STRUCTURAL UTILITY OF LAYERED VOLCANIC ROCKS E. F. Cook, University of Idaho, Moscow, Idaho

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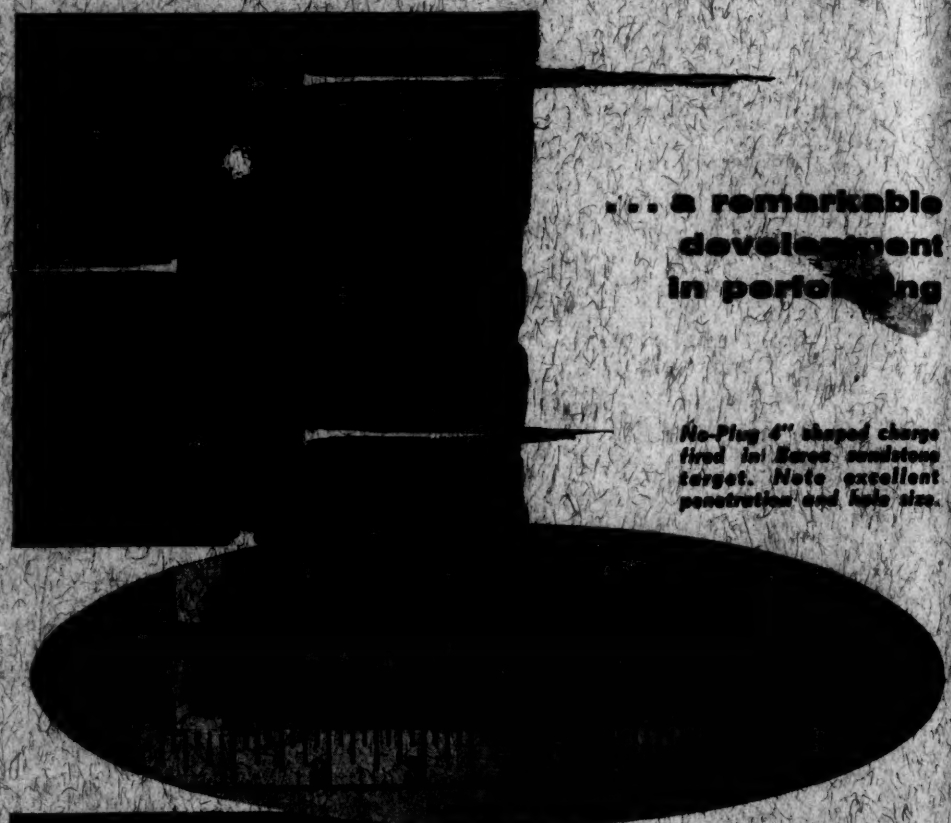

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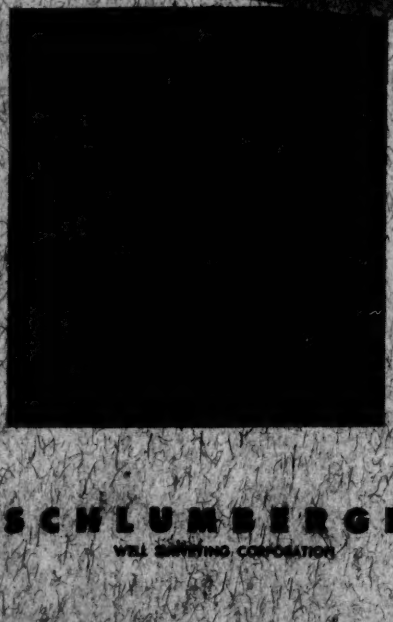

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